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April 1941

TECHNOLOGY REVIEW

APR -2 1941

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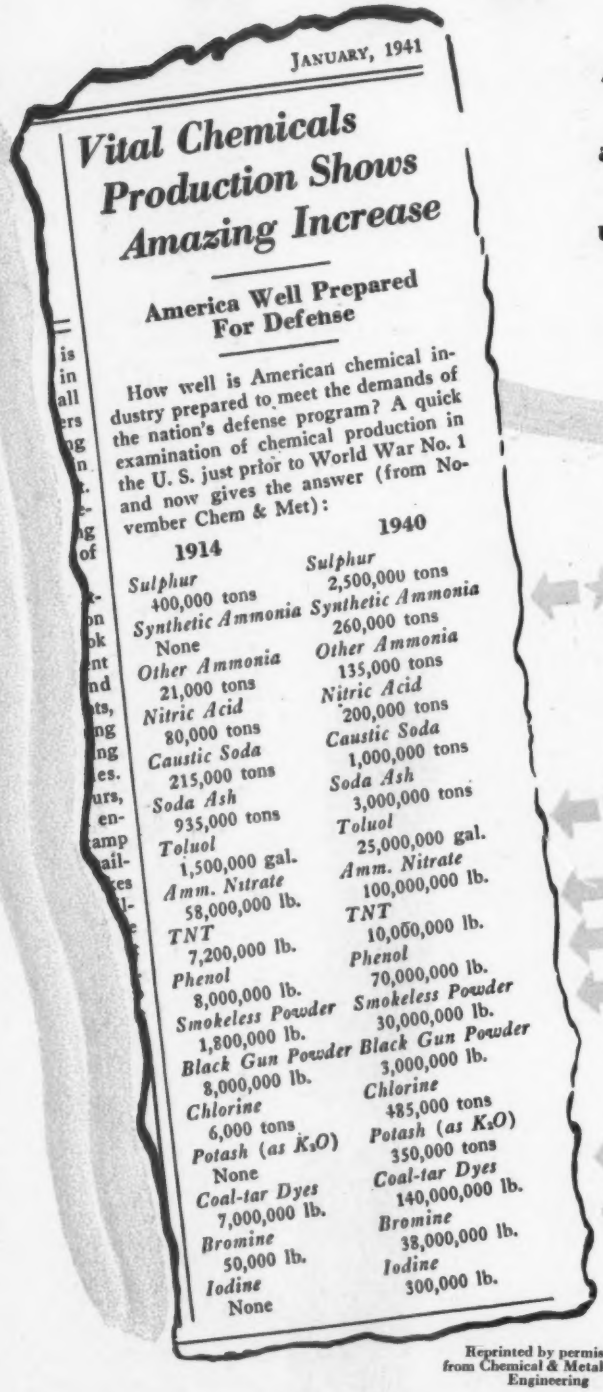
BADGER



JANUARY, 1941

Vital Chemicals Production Shows Amazing Increase

America Well Prepared For Defense

How well is American chemical industry prepared to meet the demands of the nation's defense program? A quick examination of chemical production in the U. S. just prior to World War No. 1 and now gives the answer (from November Chem & Met):

1914	1940
Sulphur 400,000 tons	*Sulphur* 2,500,000 tons
Synthetic Ammonia None	*Synthetic Ammonia* 260,000 tons
Other Ammonia 21,000 tons	*Other Ammonia* 135,000 tons
Nitric Acid 80,000 tons	*Nitric Acid* 200,000 tons
Caustic Soda 215,000 tons	*Caustic Soda* 1,000,000 tons
Soda Ash 935,000 tons	*Soda Ash* 3,000,000 tons
Toluol 1,500,000 gal.	*Toluol* 25,000,000 gal.
Amm. Nitrate 58,000,000 lb.	*Amm. Nitrate* 100,000,000 lb.
TNT 7,200,000 lb.	*TNT* 10,000,000 lb.
Phenol 8,000,000 lb.	*Phenol* 70,000,000 lb.
Smokeless Powder 1,800,000 lb.	*Smokeless Powder* 30,000,000 lb.
Black Gun Powder 8,000,000 lb.	*Black Gun Powder* 3,000,000 lb.
Chlorine 6,000 tons	*Chlorine* 485,000 tons
Potash (as K_2O) None	*Potash (as K_2O)* 350,000 tons
Coal-tar Dyes 7,000,000 lb.	*Coal-tar Dyes* 140,000,000 lb.
Bromine 50,000 lb.	*Bromine* 38,000,000 lb.
Iodine None	*Iodine* 300,000 lb.

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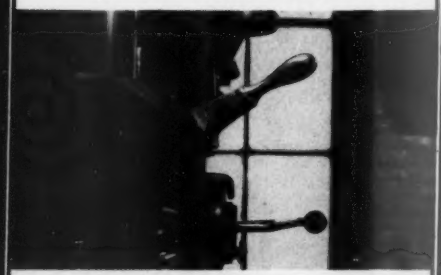

LOST MACHINE HOURS. A chip in the eye can shut down a machine for hours, days . . . *or until you train a new man,* who may not be easy to get. Production is lost. Schedules may be disrupted.

COMPENSATION AND MEDICAL CARE. These costs are more or less insured . . . *but an easily avoidable accident helps no one's risk-rating,* and these costs run on into hidden costs that are *not* insured.

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The plain fact is this: A complete program of American Eye-Protection will return more . . . dollar for dollar . . . than any other equipment investment you can make. Your AO Industrial Representative will show you *for how little* you can give *all* your workers comfortable American Goggles, fitted with Super-Armorplate Lenses, deep-curved for *extra* strength. *Write.*

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No. 33

Just for Fun!

A CHALLENGE

TO YOUR INGENUITY

FOR puzzle purposes, suppose that some new type photographers' light bulbs undergoing a life-test for one week burned out as follows:

Sunday: ½ of the bulbs + ½ of a bulb,
Monday: ⅓ of the bulbs left + ⅓ bulb,
Tuesday: ¼ of the bulbs left + ¼ bulb,
and so on, progressively, until
Saturday: ⅛ of the bulbs left + ⅛ bulb.

Assuming that there is only one filament in each bulb, what is the least number of bulbs that could have been left when the test ended?

If the fractions had progressed in reverse order [starting with ⅛ of the bulbs + ⅛ of a bulb on Sunday]; would the final result have been the same? Why?

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THE TABULAR VIEW

Isentropic. — As the air becomes more and more the front line of war, knowledge of air fronts in meteorological terms has become of greater and greater military value. Long-range weather forecasting may hence be a useful by-product of the present struggle, and thus again the stimulation of meteorological knowledge by martial demands will have been demonstrated. The relationship between war and weather is sketched in this issue of The Review (page 247) by SVERRE PETTERSSEN, Professor of Meteorology in charge of work in the subject at the Institute. Dr. Petterssen's explanation of advanced methods of air-mass analysis has the authority of his distinguished career as one of the group of Scandinavian students of the weather upon whose work modern technique is based. Before coming to Technology in 1939 to take charge of meteorological research, Dr. Petterssen headed for seven years the Forecasting Institute in Bergen, Norway.

Unlike Likes. — Talk being so familiar a phenomenon, the interest which men take in analysis of it is the more readily understandable. Chief difficulty with many discussions of the ubiquitous subject, however, is that such discussions offer little which is basically new. The penetrating essays which BENJAMIN LEE WHORF, '18, has earlier contributed to The Review have rightly been regarded as exceptional by readers, some of whose comments have appeared in our Mail Returns column. In the present issue (page 250) Mr. Whorf pushes his inquiry farther, showing how some languages resemble chemical compounds in the way their sentences are constructed, and others resemble mechanical mixtures. Mr. Whorf's studies in speech and logic are the outgrowth of an avocation commenced over a decade ago. He has lectured on linguistics at Yale.

Atomic Geometer. — To BERTRAM E. WARREN, '24, Professor of Physics at the Institute, diffraction of x-ray beams by various materials has disclosed rare and interesting knowledge of the infinitesimal worlds within crystals, liquids, and glass. His work on the structure of water was reported in The Review for February, 1939. In this issue (page 253) Professor Warren discusses how the geometrical demands of atoms govern the structure of glass. His article reports advances in this field of research which have been made since Philip M. Morse, Professor of Physics and Editorial Associate of The Review, summarized the situation in our issue for April, 1937.

To Instruct. — After varied executive experience in metallurgical industries, A. C. CARLTON, '17, became a teaching administrator through his post as curator of fuels and metals in the Chicago Museum of Science and Industry, which he describes for The Review (page 256) as an example of the modern museum in its function as an educational institution.

THREE JOBS...ONE IRON

Versatility in cast iron — especially when economically obtained... is a valuable asset for both the foundry and the user.

Consider, for example, the experience of a manufacturer of Diesel engines — and the economies effected by using one base iron to meet three distinct sets of requirements. One set calls for ability to resist wear and hold pressure at operating temperatures, the second for toughness and pressure resistance at the same temperatures, and the third for the wear resistance and toughness essential for timing gears and similar parts. Good machinability is, of course, a prime requisite in all three cases.

All these varied requirements are being met by using the same Chromium-Molybdenum (0.60—0.70% Mo.) base iron; only slight changes in the analysis are necessary. The practical and economical advantages to the foundry are obvious. And the user benefits by getting reliable, machinable parts at reasonable cost.

Our booklet, "Molybdenum in the Foundry", is both interesting and helpful. A copy will be sent to all those interested free on request.

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MOLY

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MAIL RETURNS

Australia at War

From an Alumnus in Australia recently came to President Compton the letter below, which The Review is privileged to publish. Written on January 7 of this year, it gives in summary form an understanding of the determination and courage which have had other gallant expression in lands far from the Antipodes.

FROM UTAR JAMES NICHOLAS, '08:

Receipt of your annual President's Report for 1939–1940 has inspired me to write to you for the first time since my graduation in 1908. We Australians deeply appreciate promise of vast help outlined in President Roosevelt's inspiring message to Congress on January 6.

Fellow students at Technology in my day thought that Australia was a country of kangaroos, boomerangs, and bushwhackers. Today we are manufacturing and delivering airplanes, tanks, guns, rifles, and ammunition on a scale never before believed possible in this country. Our Australian diggers are fighting in North Africa. All are volunteers, for we have no conscription. Fifty thousand airmen — pilots and crews — are training for the Empire Air Scheme.

I cheerfully pay one-half of my income to the income tax department and will willingly pay still more when necessary. For we are going on — no matter what the cost in blood and treasure — until we are secure. We are all intensely loyal to our King. When we have reverses, the rate of recruiting is doubled or trebled, thus showing the temper of the people. . . .

Like Australia, you are far removed from the din of battle. May it never reach your shores.

Melbourne, Australia

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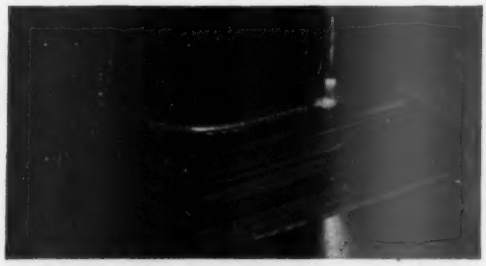
Here are a few of the things you can do—

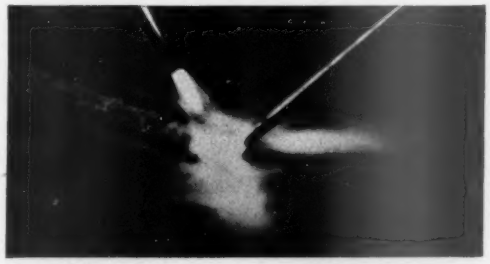
with the help of these dependable products . . .

In practically every industry—large or small—oxy-acetylene processes are used to speed production—to improve results—to lower costs—and to maintain efficiency of plant and equipment. A few of the things you can do with the help of Linde Oxygen, Prest-O-Lite Acetylene, and Union Carbide are outlined here.

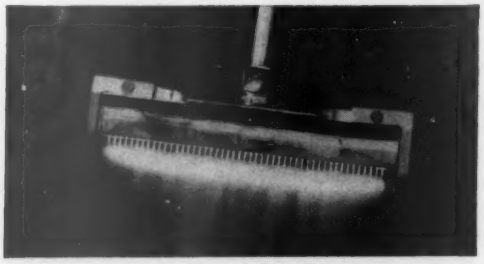


Shape Steel—Fast and economical flame-cutting reduces machining, grinding, and chipping operations. There are hand-cutting blowpipes and cutting machines for almost every cutting, gouging, and shaping need.

Form Metals—The oxy-acetylene flame is being used increasingly for such operations as "wrinkle-bending" of pipe and for straightening damaged metal sections. It should be applied where intense heat is required.



Join Metals—Oxy-acetylene welding makes it possible to join practically any metals, similar or dissimilar. Production oxy-acetylene welding is used wherever speed, strength, and good appearance are required.



Treat Metals—Oxy-acetylene flames are used both to surface-harden and to anneal steel and iron parts. The same flames are used for descaling to facilitate machining, and for cleaning to make paint last longer on steel.

Linde has the organization and the experience to help you use Linde products and processes profitably. If you want to know more about how to use the processes outlined above, *ask Linde!*

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IN modern blitzkrieg armored forces must travel far and fast without breakdown or delay. Yet even the heaviest steel tank treads are surprisingly short-lived under the grind and pound of field operations. Engineers thought of shoeing these caterpillar-footed treads with rubber, since rubber far excels metal in resisting abrasive wear. Tests proved it was the answer. Not only do these rubber-armored treads long outwear naked steel, but they give Uncle Sam's new iron cavalry greater maneuverability, greater speed to deliver a knockout punch. Industry too finds this rubber-armoring process of great value in protecting equipment used in handling ores and other highly abrasive material. The G. T. M. (Goodyear Technical Man) will be glad to tell you about it. Write: Goodyear, Akron, Ohio or Los Angeles, California — or call the nearest Goodyear Mechanical Rubber Goods Distributor.

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VOLUME 43 NUMBER 6

THE TECHNOLOGY REVIEW

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EDITED

AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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From a photograph by Rene W. P. Leonhardt

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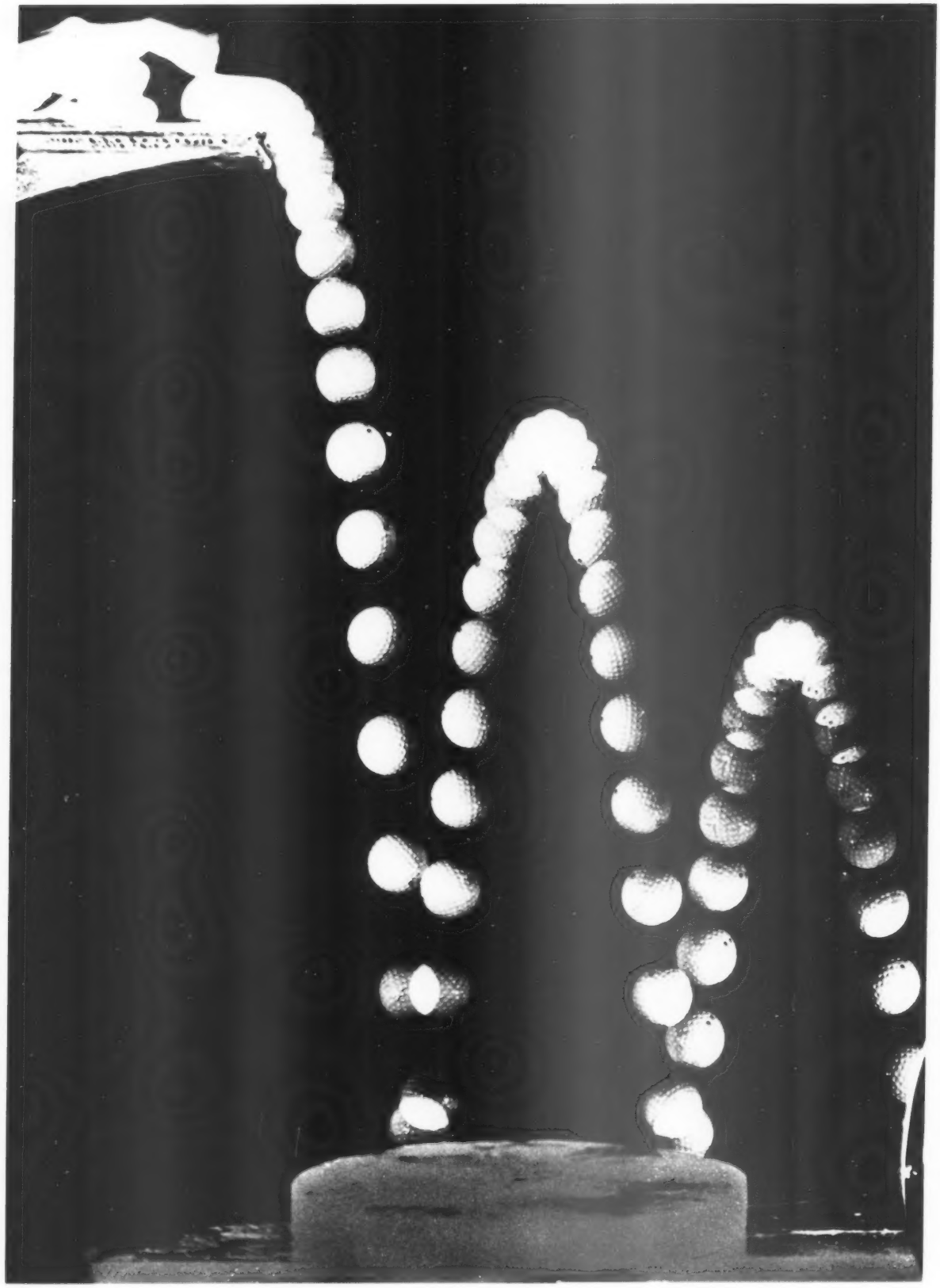


VIOLENT

THE
TECHNOLOGY
REVIEW

Vol. 43, No. 6 April, 1941

The Trend of Affairs

Small Arms for Industry

IF the big machine tools — the roll grinders and the turret lathes — are the heavy artillery of industry, its small arms, complete with pistol grips and trigger switches, are the portable power tools. In 1937, out of a total machine-tool production valued at $216,000,000, such portable tools accounted for less than $20,000,000, a figure which indicates sufficiently well where the brunt of the work falls. In the hands of assembly men, construction workers, and millwrights, however, these easily handled tools are daily saving countless man-hours and performing operations which often would otherwise remain undone.

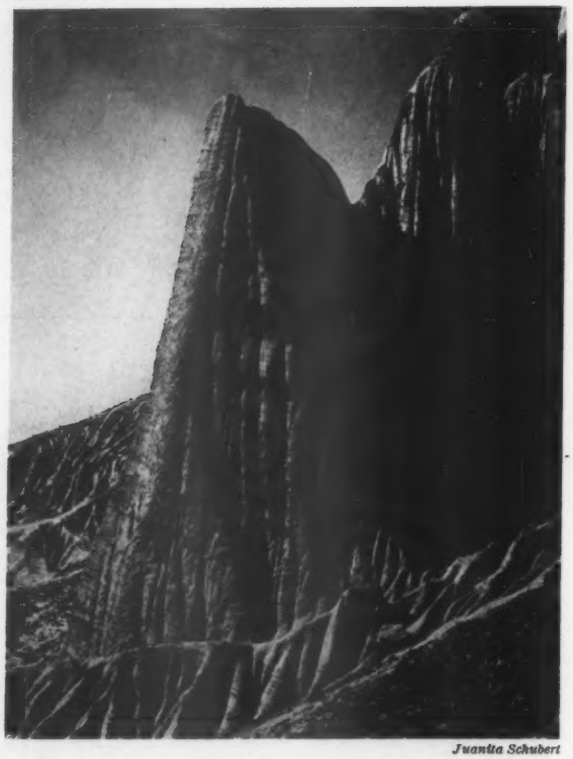
To achieve precision and high production, most machine tools sacrifice portableness and the ability to be guided by hand over irregular and shifting surfaces, for the two sets of conditions are virtually incompatible. The dentist who sights an interesting cavity in a wisdom tooth reaches for his portable drill, not for a mechanically guided boring mill; the welder who wishes to smooth a pass in the depths of a partially completed battleship brings his tool to the work and not vice versa. Half-built locomotives and airplanes, let alone coal mines and concrete buildings, are essentially not mobile. They must be treated not in the manner of a gear blank but as was Mohammed's mountain.

◀ *A new way of teaching school is presented in this multiflash photograph of a bouncing golf ball, one of a group of experimental pictures made at the Institute by Harold E. Edgerton, '27, Associate Professor of Electrical Measurements, and Francis W. Sears, '20, Associate Professor of Physics. Their work is discussed on page 244.*

Hand tools, of course, have the necessary flexibility of movement, but they are slow. A husky miner pounding at rock with a steel and a hand hammer can bore little more than five to ten feet of hole during an eight-hour day, whereas a modern pneumatic drill during the same time can penetrate 100 to 150 feet of rock. Virtually all forms of hand tools, including brushes, shears, saws, files, wrenches, screw drivers, and surely fifty-seven varieties of hammers, can be obtained in powered portable versions. The power source is almost exclusively electrical or pneumatic, the typical tool being driven by a high-speed universal motor through reduction gearing. Among other substitutes for human muscle is the gasoline motor; a European firm, for example, has designed a compact one-horsepower engine which can be strapped to the back like a knapsack.

As might be expected, power-driven portable tools are much faster than are their hand equivalents. One man with a pneumatic paving breaker can do as much work as can twelve or fifteen men with steels and sledges. One man with an electrically driven surface grinder can replace four or five working with hand tools. One carpenter with a portable electric saw is as effective as ten men with hand saws in erecting concrete forms. And so it goes.

In certain circumstances the power-driven tool is not only faster but also better. It can ram a mold in the foundry more thoroughly and uniformly than the molder can by hand. It will vibrate a lean, harsh concrete mix into place, whereas a crew without power would add more water and produce a more workable but weaker concrete. When supplied with an adjustable clutch, a nut runner will set nuts to within 10 per cent of a predetermined tension, much closer than can be expected of handwork. In this fact lies another reason why the air above the men on a modern automobile assembly line is cluttered with dangling, counterweighted power tools. Some jobs, such as smoothing irregular surfaces and removing burrs, cannot be done



Juanita Schubert

On these pages, textures in stone unused and stone at work. This is in Red Canyon, a section of the Mohave Desert, in southern California.

at all by a rigidly guided machine tool and are frequently uneconomical when they are performed by hand. As a result of the stress of world events, the most vital field for the portable power tool is at present the airplane industry. The greater part of the work involved in the production of the airplane structure is handwork, for the bulk and shape of the growing frame quickly preclude much machine work. The biggest items in the handwork are drilling the rivet holes and setting the 45,000 rivets in the typical small plane or setting the 450,000 rivets in the four-motored bomber. Here the usual situation is reversed: While much invaluable work is done by multiple-tooled floor machines, the brunt of the load falls on pneumatic or electric drills and hammers.

In many ways these portable tools are as striking an example of weightsaving and compactness as are the airplanes they help put together. Specifically, the most important elements in obtaining light weight with no sacrifice of ruggedness have been magnesium and aluminum die castings and heat-treated alloy-steel gears. Tiny grinders are available which can be held in the hand, like an outsize pen. Weighing well under a pound, one type is driven by an air turbine which can deliver one-sixth horsepower and which turns at 75,000 revolutions a minute under no load. Drills capable of boring holes up to one-quarter inch diameter in steel and weighing about two-and-a-half pounds have long ceased to be a novelty, while heavy-duty grinders built to spin eight-inch wheels need weigh no more than fifteen pounds.

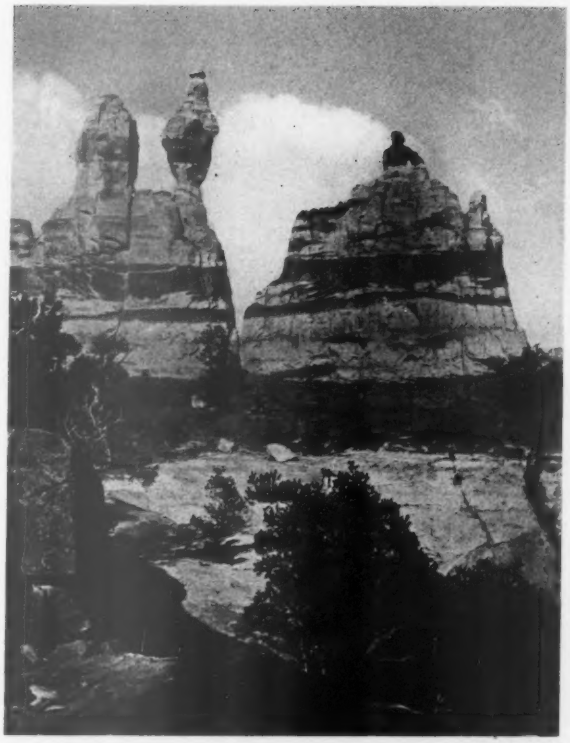
Potpourri

TALES of the sidehill ranger — the mythical beast whose starboard legs are shorter than those to port, for greater convenience in spiraling around and up the hills on which he loves to live — are recalled by the issuance to Henry Ford of a patent for a "hedge-hopping" tractor. The machine is designed with a novel wheel suspension which provides that all the wheels may be raised or lowered relative to the tractor itself. For plowing, when it is necessary that one of the drive wheels run in the bottom of the furrow and the other on the unplowed surface, the sidehill-ranger feature operates, the furrow wheel being dropped so that the tractor body proceeds without the list to one side which has heretofore been inescapable. When all wheels are arranged to provide maximum clearance of the body aboveground, the tractor may be used for the cultivation of relatively tall corn and similar crops. The wheel suspension utilizes cylindrical sleeves which can be locked in any of several rotatable positions around the axle tube. When the sleeve is rotated by means of a worm gear, the wheel is raised or lowered as desired. Adjustments can be made by the driver with the aid of an ordinary wrench. ¶ For late-evening kitchen lunchers a new wrinkle is a handle tab which, embedded in the paraffin sealing a jar of jam or jelly, both protects the preserves and eliminates the need for jimmying off the coating. The new device consists of a nickel tab from which a flat stem projects at right angles. The tab is placed on top of the preserve with the stem sticking straight up. The paraffin, poured on

Roofing slates

Fred G. Korth

as usual, covers the tab, but the stem sticks up through the paraffin seal, waiting the grasp of the luncher. ¶ To speed the mails still faster, highway postal-car service, utilizing specially designed motor buses, is being tested on three pilot routes. Equipped with facilities duplicating those in railway mail cars, one such bus is making regular daily round trips to serve towns along the 141-mile route between Washington, D. C., and Harrisonburg, Va. Pickup, sorting, and delivery of mail en route by means of the vehicles would allow the small community to have service equaling that enjoyed by larger centers. Some of the nation's 48,000 communities which lack railroad connection have been relying on contract motor-truck service. The mail for these communities has been sorted in a city post office, sealed into sacks for each town, and dropped off along the route, with mail for the city being picked up from each town on the return trip. The experimental service now being tested by the Post Office Department is expected to set standards for all vehicles destined to serve as traveling post offices for the better meeting of the needs of the star route towns. ¶ Plans for large-scale production of wind-power plants, reported as being formulated by the German electrical industry, call for outfits of three classes, with capacities up to 100 kilowatts, 100 to 1,000 kilowatts, and 10,000 to 20,000 kilowatts, respectively. The cost of generating electric power by wind is estimated as between .08 and .1 reichsmarks a kilowatt hour; the reichsmark nominally equals forty cents in United States currency. ¶ High price of the beads, plus the cost for extra labor, offsets the advantages to be had from adding tiny glass beads to the paint in highway traffic lines, according to California investigators. The beads, averaging about 1/100 inch in diameter, make the guide stripes on roads brighter and more effective at night by reflecting the headlight beams of automobiles and returning the color of the painted lines. Such lines, it has been found, wear well, one of them being easily discernible at night even after some twenty months of wear. The beads were judged economically justified for special locations. ¶ Bones as well as veins can serve as avenues for blood transfusions, two Philadelphia physicians report. Injection directly into the veins is in some conditions difficult if not impossible; hence the finding that substances injected into the bone marrow reach the blood stream without apparent change and in little more time than when directed into the veins offers encouragement in cases where transfusion is essential. Sugar solutions, blood plasma, and salt solutions may also be introduced in the system of a patient by transfusion through the marrow. Trying the method on seventeen patients, the doctors report meeting but one failure. ¶ Old salt mines, occupying 160 acres under the southwestern part of the city of Detroit, are regarded as admirable shelter for the whole 1,618,549 population of the city in the event of war needs. The caves are 1,100 feet deep, their ceilings supported by great pillars of salt. The temperature is constant at 58 degrees. People taking air-raid refuge in the old mines would not be able to hear even an intense bombardment going on above. The mines could also serve as shelter for essential industries, as a hospital, or as an ammunition dump, in the judgment of military officials. More than twenty-five miles of passageways fifty feet wide and twenty-two feet high are available in the mine.



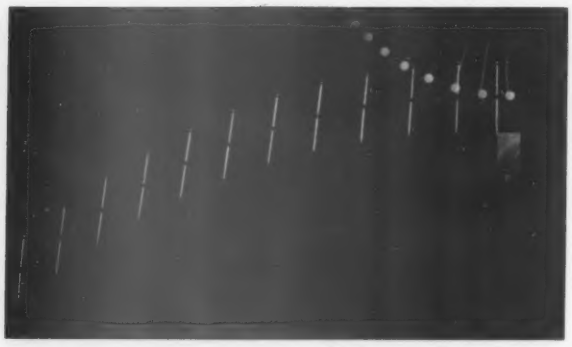
Paul J. Woolf

Gateway of the Giants, New Mexico

A cobbled street in Charleston, S. C.

F. S. Lincoln, '22

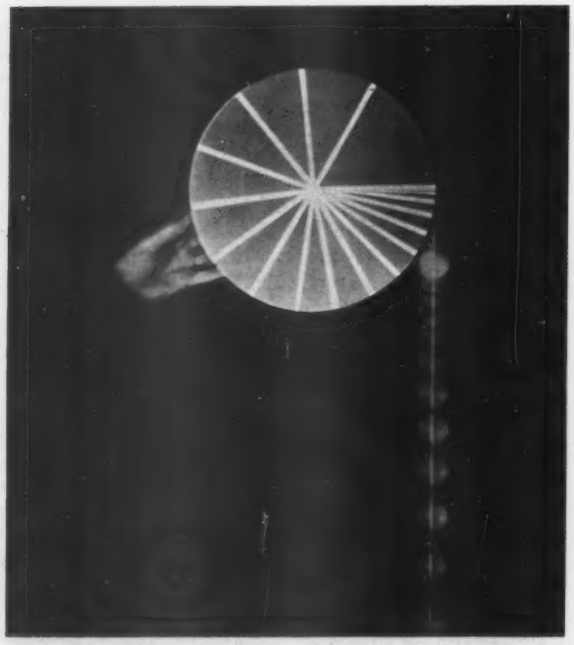
Successive photographs of a wooden bead in flight, taken at uniform intervals of time, show the path taken by a body in free space when it is projected at an angle. The horizontal distances covered during the intervals are equal; the vertical distances decrease steadily during the upward course, increase steadily on the way down. The path as a whole is a parabola.



Motion of a rod struck at its center of gravity, indicated by the wide band. No rotation occurs; the center of gravity moves in a parabolic path resembling that taken by the bead in the adjoining picture. Downward acceleration and horizontal velocity are uniform. The pendulum that struck the blow appears at the upper right.

Pictures That Teach

ANY physicist will tell you with vehemence that the fundamentals of his science are beautiful in their simplicity. The rippling rhythms of harmonic motion, the suave sweep of parabolic paths, the cunning counterpoint of deceleration during ascent, acceleration during descent — all of these and others combine as he rhapsodizes, and combining, they compose a compelling symphony of pedagogy and science merged. Only sour note, to the layman or to the beginning student, is that the physical phenomena embodying these motifs generally happen a little too fast to let the observer sense them bit by bit. The demonstration experiments upon which the lecturer relies to illustrate the fundamental laws and theories being expounded do afford the illustration, but so swiftly that it often must be taken on faith. If the acceleration of gravity, for instance, were very much smaller than it is, so that the motion of a swinging pendulum were slowed down until it could be followed almost step by step, simple harmonic motion might be a concept more readily grasped.



The relation between linear and angular acceleration is demonstrated as the weight drops, unrolling the cord wrapped around the disk. Motion of the disk may be judged by the spacing of photographs of the radial line on its surface. The acceleration of the falling weight equals the radius of the disk multiplied by the angular acceleration of the disk.

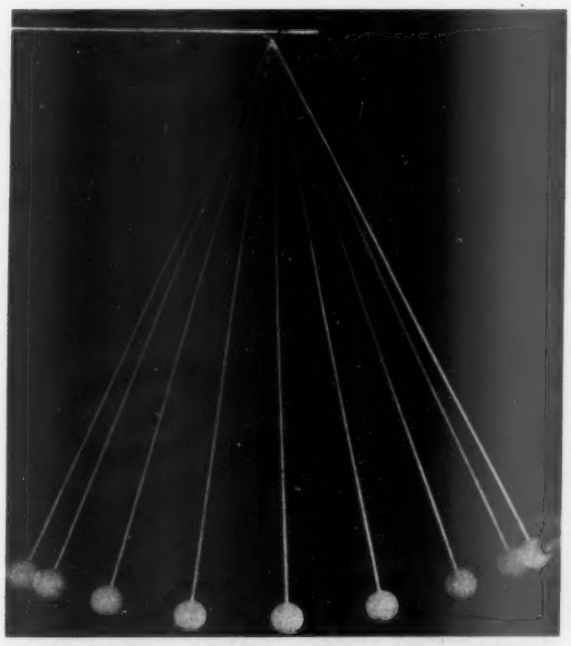
Two bodies released simultaneously — one dropped vertically, the other projected horizontally — fall at the same rate and land at the same time. Horizontal velocity of the projectile here is uniform. The mechanism does not release the two spheres exactly simultaneously; exposures at about 1/30 of a second show the ball at the left to have been given a tiny head start.

The same rod struck slightly above its center of gravity. Rotation has been acquired in addition to translation, but the center of gravity follows the same parabolic path, even though the rod rotates with uniform angular velocity about the center of gravity, completing one full revolution as the positions of its narrow-banded top indicate.

When it has been struck slightly below its center of gravity, the rod rotates in the other direction, completing a revolution during its flight. Rotation takes place with uniform angular velocity about the center of gravity. The center of gravity, however, sticks to the smooth parabolic path which may be traced by the successive positions of the wide band at the middle of the rod.

Better than mere slowing down, however, would be a method of breaking the demonstration phenomenon into a series of occurrences, allowing for a comparison of units in the series and consequent comprehension of what took place between them. Slow-motion moving pictures would readily enough provide the slowed-down demonstration. A series of still pictures, taken at very short intervals of time, gives the even more desirable sectionalized view of what actually happens when a swinging pendulum illustrates harmonic motion or a stick shows the path of a body moving in free space.

The new pedagogical technique which is illustrated in the accompanying photographs, and with which Harold E. Edgerton, '27, Associate Professor of Electrical Measurements, and Francis W. Sears, '20, Associate Professor of Physics, have recently been engaged at Technology, promises not only to provide answers to the problems suggested thus far in this account but also to offer other useful teaching applications. The multiflash photographic technique perfected by Professor Edgerton has been applied by him and Professor Sears to many of the demonstrations used by the latter in initiating first-year



Simple harmonic motion is illustrated by these standard-interval pictures of a swinging pendulum. The maximum velocity occurs at the center of the swing, with zero velocity at the end. The greatest acceleration takes place at the point where the pendulum is traveling at the slowest rate. The greatest velocity occurs at the point where acceleration is last.

When the bead is projected vertically rather than at an angle, horizontal motion may be ignored. Here uniform deceleration during upward flight and uniform acceleration during downward drop are clearly shown. Distances moved between flashes show that downward velocity of the sphere as it passes the starting point equals the upward velocity which it had at that point.

men into the elements of physics. Reducing the demonstrations to series of successive stop-motion flashes, the photographs make it possible to analyze and discuss the phenomena in detail. The photographs have been used as slides to illustrate the demonstration lectures; plans call for their being used later as problems for analysis.

The full implications of this form of visual education are of course not yet ascertained. Student response to the new technique has been excellent, so that much further use of the idea may well be made.

Ares and the Actuaries

MODERN war, as it brings death and destruction more bitterly home to civilian populations than ever before, lays added stress upon the interdependence of the community. This consequence takes a pecuniary expression in present British planning for the compensation of those whose property suffers damage; such damage, it is held, should be regarded as a community loss rather than as an individual loss, and hence the community as a whole should bear the burden of compensation. Insurance in the usual sense, however, is considered not practicable, because no basis for actuarial calculation is to be had. Not yet have we been able to compile tables of expectancy of the visits of the bomber.

The war damage bill embodying the government plan is frank in regarding the measures as a compromise between insurance and outright compensation. A compulsory contributory compensation plan for damage to fixed property is the most important provision of the bill. Property totaling in value between six and eight billion pounds is involved in the plan, which calls for contributions payable in five annual instalments — the first in July of this year — totaling 2.5 per cent on the capital value. The total contributions are expected to amount to about two hundred million pounds. If the total compensation payable exceeds this amount, the government will take care of the difference up to an additional two hundred million pounds. Subsequent excess loss is to be met half by government and half by increases in contributions payable. Compensation, under the plan, will be paid for all damage occurring during the first two years of the war — up to the last of August of this year. Additional legislation will be required should the war continue beyond that time. Payments necessary to provide for immediate repairs to essential properties, as the bill is drawn, will be made as the repairs are done. Other payments will be deferred, carrying interest at 2.5 per cent a year, and will presumably be made after the conclusion of hostilities.

Insurance against war risks of movable business assets, such as machinery and equipment, is provided for in a second plan. This insurance is to be compulsory for property exceeding one thousand pounds in value, and voluntary for property valued at less than that figure. Premiums are to be at the rate of 1.5 per cent for the period from the beginning of the war to the end of September of this year. Personal and household effects are to be insured under the provisions of a third scheme, which is entirely voluntary, at a rate of 1.5 per cent a year, the policies being issued on an annual basis. A total of fifteen hundred pounds is the limit which may be insured by one individual under the plan, with an addition of not more than five hundred pounds for a motor vehicle.

Westinghouse

Not the hands of an organist but those of an inspector checking arc extinguishers designed to do more efficiently the work formerly done by fuses. Capable of putting out an electric arc in 1/100 second, these devices prevent damage from short circuits.

Technology and Society

STRONG evidence of the increasing scope of governmental activity which S. McKee Rosen and Laura Rosen, authors of *Technology and Society*,* emphasize as characteristic of our time is the extent to which such a volume as theirs can rely upon government publications for source matter. Not very many decades ago, little more than tables of statistics were available from government as material for writers on sociological topics. In recent years, notably in the last decade and a half, have been added thoroughgoing economic and social analyses in dozens of fields, for the preparation of which able minds have been brought from nongovernmental agencies and for which virtually all techniques of exposition and portrayal are utilized.

Thus this volume draws freely on such official documents as the comprehensive study, *Technological Trends and National Policy*, issued in 1937 by the science committee of the National Resources Committee; various publications of the Works Progress Administration; and the findings of the President's Research Committee on Social Trends. The authors would have performed a highly valuable function if they had no more than siphoned in this fashion useful material from these stocks — stocks whose very (*Continued on page 277*)

* New York: Macmillan, 1941. xiv, 474 pages, $3.00.

Wars and Weather

Three Military Conflicts Have Given Rise to Noteworthy Advances in Weather Science; Long-Range Forecasts a Probable By-product of the Present Struggle

By Sverre Petterssen

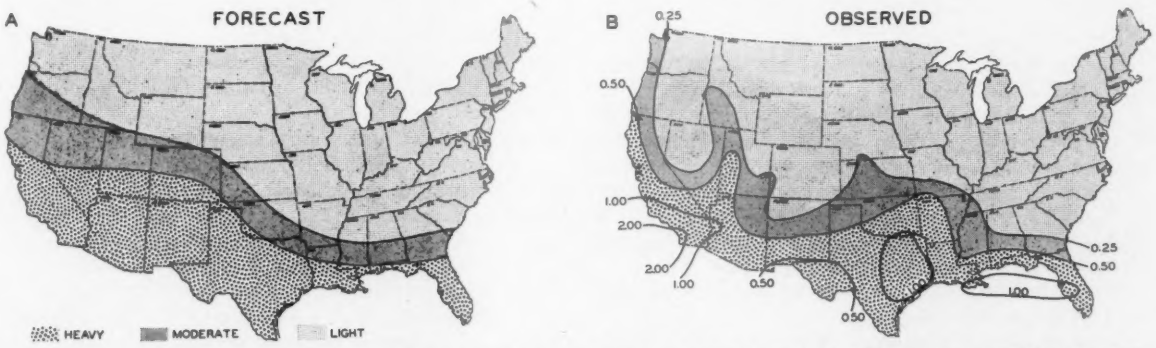
TYPICAL of a large number of weather phenomena is the fact that they develop around an unstable state of equilibrium, so that a small impulse may give rise to great events. The same condition is true, to a certain extent, of the history of weather forecasting. Wars and storms are quite frequent phenomena in Europe, and weather forecasting was initiated through a coincidence of a war and a storm. Actually, a singular feature of the history of weather forecasting is that the most noteworthy advances have resulted from three major impulses connected directly with wars.

Crimean War Starts Weather Forecasting. In 1854, during the Crimean War, a storm — or what meteorologists today would call a cyclone — arrived in the Black Sea, causing considerable damage to the French fleet and wrecking completely the battleship *Henri IV*. By this time the French astronomer Leverrier had won world fame on account of his "forecast" of the existence of a new planet. As is well known, Leverrier computed that an unknown planet existed within our solar system, and when the telescopes were directed to the computed spot, the planet Neptune was found. Napoleon III, who had invested much money and prestige in the Crimean War, apparently thought that if the scientists could forecast the existence of an unseen planet, they should also be able to forecast storms and other weather. He therefore charged Leverrier with what proved to be a difficult task — that of organizing a system for weather forecasting.

At that time there were no weather bureaus to turn to as sources of information, and no organized network of reporting stations existed. But from universities, from observatories, and from the few stations keeping meteorological logs, Leverrier was able to collect enough data to plot primitive weather maps and study the Black Sea storm post mortem. He found that the storm could be traced from one weather map to another, since it had developed and moved toward the Black Sea on a regular path and with a fairly constant speed. The conclusion he drew from this fact was that if observations made at a large number of stations could be reported with sufficient speed to some central office, one could, by plotting and analyzing weather maps, follow a storm from one chart to the next and extrapolate its future movement.

By this conclusion Leverrier had not solved any problem related to the physics or the dynamics of storms; he had merely shown that a simple freehand extrapolation of a storm path could give valuable results. An outburst of enthusiasm followed his report. Within a few years meteorological institutes and networks of reporting stations were established in most countries, and the first experiments with storm warnings and weather forecasting were commenced.

But the problem was soon found to be more intricate than had been anticipated. The Black Sea storm, a pronounced and clear-cut case, was easy to handle. Often, however, storms seemed to develop out of unstable conditions, and to find the small impulse which released these great events was difficult. Furthermore, very little was known of the mean, or normal, state of the atmosphere; and before something was known and understood thereof, it was difficult to handle the perturbations which were superimposed on the general circulation. Nevertheless, a sort of weather-forecasting service was developed on a purely empirical basis. The art of



An example of long-range forecasting. Map A is an M.I.T. five-day forecast of rainfall for the period February 22 to 26, 1941. Map B is rainfall actually observed during the same period.

forecasting consisted of memorizing similar situations, empirical rules, and rules of thumb. Thus, a young forecaster might have been advised by his senior colleague as follows: "If the barometer falls in Paris and rises in London, there will usually be an east gale in the English Channel." Why the barometer fell in Paris and why it rose in London were questions of theoretical interest only, which were left for the physicists to solve, if they felt so inclined. The empirical rules were mostly of local or regional value, with the result that a forecaster in London could learn but little from his colleague in Washington and vice versa.

The optimism created by Leverrier's report was soon followed by pessimism, and the problem of weather forecasting on a rational scientific basis was not seriously attacked until about the time of the first World War.

World War I and the Polar Front. The first World War gave a new and considerable impetus to weather forecasting. In the belligerent countries better forecasts were needed for the planning of aerial, gas, and other warfare, and in the neutral countries of Europe the food shortage caused consideration to be given to improvements in the weather service for the benefit of agriculture and fisheries. In Norway, which was heavily dependent on the day-to-day success of fishing, Vilhelm Bjerknes organized a small group of physicists to found weather forecasting on a scientific basis.

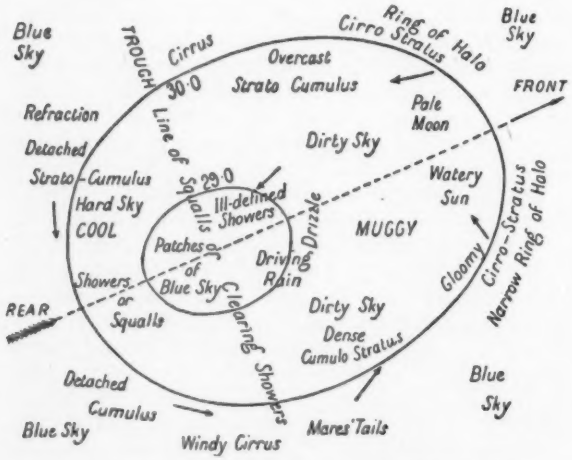


Fig. 1. Pre-1914 ideas of the distribution of clouds and weather around a cyclone. The closed curves are isobars around a low-pressure center.

Areas of low pressure (now called "cyclones," or "depressions") had long been known to be associated in general with high winds and bad weather. Figure 1 shows, diagrammatically, the distribution of clouds and weather around a cyclone according to the ideas prevailing prior to World War I. After studying a large number of individual cyclones, Jakob Bjerknes tried to draw a model, or a blueprint, of a cyclone in greater detail, such as the sketch in Fig. 2.

The most remarkable result of this investigation was the finding that the distribution of temperature, wind, and so on, around a cyclone is not continuous but is discontinuous. A tongue of warm air from the south

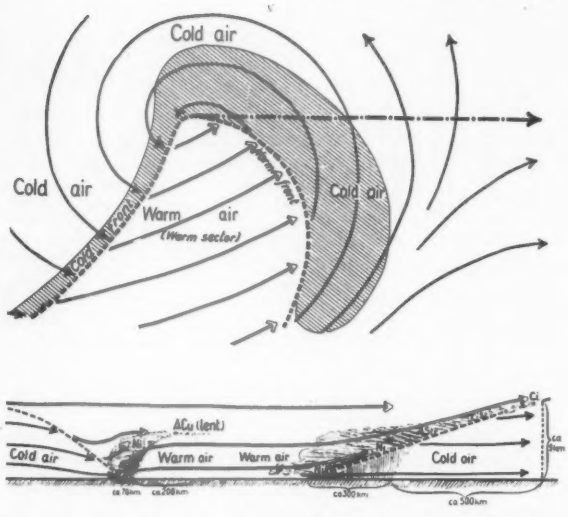


Fig. 2. Model of a cyclone, after Jakob Bjerknes and Halvor Solberg. The typical cyclone is built up of two air masses separated from one another by the polar front. The upper portion of the diagram shows the conditions along the earth's surface; the lower portion is a cross section through the cyclone south of the center. Ni = nimbus; ACu = alto-cumulus; AStr = alto-stratus; CiSt = cirro-stratus; Ci = cirrus.

extends into the center of the cyclone, where the pressure is lowest. The tongue of warm air is surrounded by a mass of cold air, the two air masses being separated by a line of discontinuity. Tracing the trajectories of the two air masses shows that the cold air originated in the polar regions, and the warm air in the tropics. A cyclone is therefore built up of two air masses separated from one another by a surface of discontinuity which marks the "fighting front" of the two enemies — the tropical air rich in moisture and heat energy, and the cold and dense polar air rich in potential energy. In true wartime lingo, this fighting front was named the "polar front."

Furthermore, the systems of clouds and the areas of precipitation were found to be oriented along the polar front, as the middle portion of Fig. 2 shows. In the left-hand section of the diagram, warm air is replacing cold air; this part of the polar front was called the "warm front." In the rear of the cyclone, cold air is replacing warm air, and this portion was called the "cold front." The passages of these fronts mark the sudden changes in wind and weather.

The cyclone model indicates not only the anatomy of the storm but also the underlying mechanism. The warm air, being less dense than the cold air, will tend to rise above the frontal surfaces, the inclination of which is about 1:100, as shown in the cross section south of the storm center. Since the ascending air cools adiabatically, condensation and precipitation occur. The contrasts in heat energy along the polar front and the difference in potential energy of the adjacent air masses are the main sources of energy for the creation of winds.

Cyclones Start as Unstable Waves on the Polar Front. Since the polar front separates a more dense mass from a less dense mass, wave motion may develop along the surface of separation in the same way that waves form on a water surface. The waves may be stable or unstable.

For example, the swell on an ocean represents the stable type of wave, which has a regular wave profile and travels with an almost constant amplitude. The ordinary waves caused by wind on a water surface are stable waves if the wind velocity is slight. If the wind is strong, however, the wave amplitude increases and the wave profile grows tall and slim, until eventually the wave breaks; this is the unstable type of wave motion.

Unstable water waves are controlled by gravity, which is a stabilizing force, and by wind shear, which tends to create instability. Halvor Solberg found that the waves which occur on the polar front are controlled by gravity, by the inertia due to the earth's rotation, and by the wind shear at the frontal surface. Gravity and inertia are stabilizing forces, but wind shear tends to create instability. Hence, if the wind shear along the polar front is sufficiently strong, unstable waves will form, a fact which gives us a clue to the understanding of the origin of cyclones.

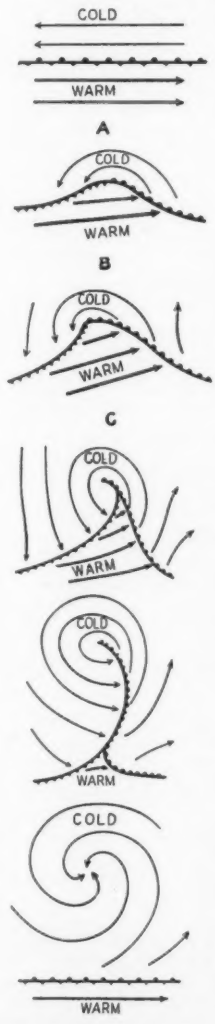


Fig. 3. Unstable waves on the polar front — the origin of cyclones. The waves increase in amplitude and the cold front overtakes the warm front, while the cyclone increases in intensity. In the later stages the fronts dissolve and the cyclone blows itself out.

In Fig. 3A the polar front separates a cold mass and a warm mass, which are streaming in opposite directions, and there is a considerable wind shear along the front. The surface of the polar front slopes northward at an inclination of about 1:100, so that when wave motion occurs on the frontal surface, the front at the ground will bulge north and south with an amplitude a hundred times that of the wave profile. In Fig. 3B a "young" wave has formed. Being unstable, this wave travels along the front with increasing amplitude; eventually the cold front overtakes the warm front, and the cyclone "occludes." The energy supply is then cut off, and the cyclone feeds for a while on kinetic energy already created. Gradually the kinetic energy is dissipated by friction. During this development, the fronts tend to dissolve and the cyclone evolves into a whirl of more or less homogeneous air. For example, the cyclone model in Fig. 2 is preceded by the wave stage and followed by the whirl stage.

The theory of frontal waves shows that only waves of certain lengths are unstable. This is because the stabilizing forces vary in strength with the lengths of the waves (see Fig. 4), whereas the unstabilizing force caused by the wind shear remains constant. If we add up the stabilizing and unstabilizing forces, we obtain four distinct types of waves on frontal surfaces:

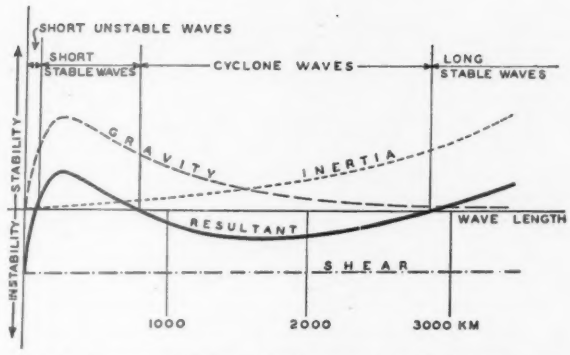


Fig. 4. Four types of waves which may occur on the polar front. Only those within the band from about 800 to 3,000 kilometers develop into cyclones.

(1) Short unstable waves, whose lengths are of the order of magnitude of a few kilometers. These waves are often visible in the sky as billow clouds.

(2) Short stable waves, which range from a few kilometers to about 800 kilometers. Within this wave band, the stabilizing forces are predominant; the waves travel along the fronts without developing into cyclones.

(3) Cyclone waves, which range in length from about 800 to about 3,000 kilometers. These are the unstable waves that develop into cyclones.

(4) Long stable waves, whose lengths exceed about 3,000 kilometers. Here the stabilizing force due to inertia is usually sufficiently strong to overcompensate for the influence of wind shear.

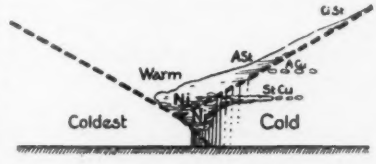


Fig. 5. Cross section through an occluded cyclone in which the cold air stream has cut under the warm air and driven it away from the earth. The occlusion process brings the potentially heavier mass under the potentially lighter mass and thus reduces the potential energy. This is the primary source of energy for the creation of storms.

A cross section through an occluded cyclone is shown in Fig. 5; the warm air which originally was at the ground is present aloft in a trough between the two cold masses. A comparison of this cross section with the one shown in Fig. 2 will reveal that the more dense and the less dense masses were originally side by side, and that after the occlusion process the former are under the latter. Hence the center of gravity of the system has been lowered, and potential energy has been liberated. As the fronts dissolve in the cyclone whirl, the available heat energy is used. In addition, considerable amounts of the latent heat of vaporization are made available through the condensation of aqueous vapor. The presence of stable waves results in a periodic conversion of potential energy into (*Continued on page 265*)

Languages and Logic

Chemical Compound or Mechanical Mixture, a Sentence Hides within Its Structure Laws of Thought Profoundly Important to the Advance of Science

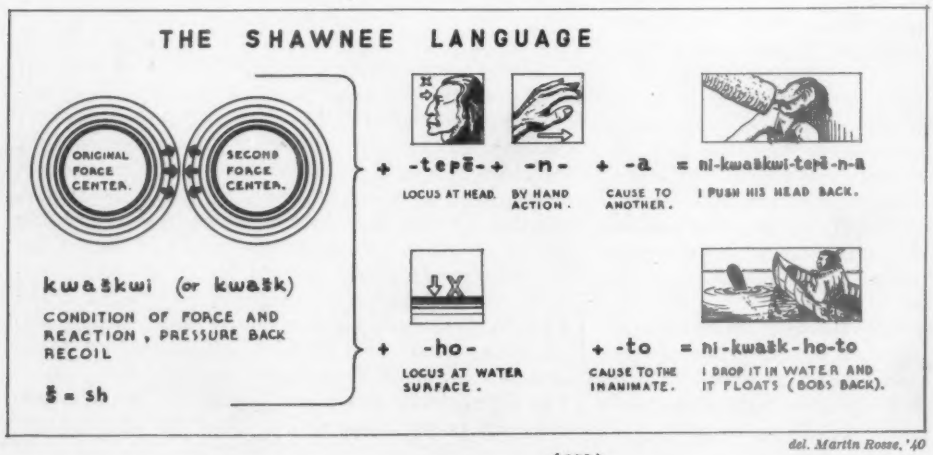
By Benjamin Lee Whorf

IN English, the sentences "I pull the branch aside" and "I have an extra toe on my foot" have little similarity. Leaving out the subject pronoun and the sign of the present tense, which are common features from requirements of English syntax, we may say that no similarity exists. Common, and even scientific, parlance would say that the sentences are unlike because they are talking about things which are intrinsically unlike. So Mr. Everyman, the natural logician, would be inclined to argue. Formal logic of an older type would perhaps agree with him.

If, moreover, we appeal to an impartial scientific English-speaking observer, asking him to make direct observations upon cases of the two phenomena to see if they may not have some element of similarity which we have overlooked, he will be more than likely to confirm the dicta of Mr. Everyman and the logician. The observer whom we have asked to make the test may not see quite eye to eye with the old-school logician and would not be disappointed to find him wrong. Still he is compelled sadly to confess failure. "I wish I could oblige you," he says, "but try as I may, I cannot detect any similarity between these phenomena."

By this time our stubborn streak is aroused; we wonder if a being from Mars would also see no resemblance. But now a linguist points out that it is not necessary to go as far as Mars. We have not yet scouted around this earth to see if its many languages all classify these phenomena as disparately as our speech does. We find that in Shawnee these two statements are, respectively, *ni-l'θawa-'ko-n-a* and *ni-l'θawa-'ko-θite* (the *θ* here denotes *th* as in "thin" and the apostrophe denotes a breath-catch). The sentences are closely similar; in fact, they differ only at the tail end. In Shawnee, moreover, the beginning of a construction is generally the important and emphatic part. Both sentences start with *ni-* ("I"), which is a mere prefix. Then comes the really important key word, *l'θawa*, a common Shawnee term, denoting a forked outline, like Fig. 3, No. 1 (page 252). The next element, *-'ko*, we cannot be sure of, but it agrees in form with a variant of the suffix *-a'kw* or *-a'ko*, denoting tree, bush, tree part, branch, or anything of that general shape. In the first sentence, *-n-* means "by hand action" and may be either a causation of the basic condition (forked outline) manually, an increase of it, or both. The final *-a* means that the subject ("I") does this action to an appropriate object. Hence the first sentence means "I pull it (something like branch of tree) more open or apart where it forks." In the other sentence, the suffix *-θite* means "pertaining to the toes," and the absence of further suffixes means that the subject manifests the condition in his own person. Therefore the sentence can mean only "I have an extra toe forking out like a branch from a normal toe."

Shawnee logicians and observers would class the two phenomena as intrinsically similar. Our own observer, to whom we tell all this, focuses his instruments again upon the two phenomena and to his joy sees at once a manifest resemblance. Figure 1 illustrates a similar situation: "I push his head back" and "I drop it in water and it floats," though very dissimilar sentences in English, are similar in Shawnee. The point of view of linguistic relativity changes Mr. Everyman's dictum: Instead of saying, "Sentences are unlike because they


THE SHAWNEE LANGUAGE
ORIGINAL FORCE CENTER.
SECOND FORCE CENTER.
kwaškwi (or kwašk)
CONDITION OF FORCE AND REACTION, PRESSURE BACK RECOIL
š = sh
+ -tepē- + -n- + -a = ni-kwaškwi-tepē-n-a
LOCUS AT HEAD.
BY HAND ACTION.
CAUSE TO ANOTHER.
I PUSH HIS HEAD BACK.
+ -ho-
LOCUS AT WATER SURFACE.
+ -to = ni-kwašk-ho-to
CAUSE TO THE INANIMATE.
I DROP IT IN WATER AND IT FLOATS (BOBS BACK).

del. Martin Rosse, '40

Fig. 1. The English sentences "I push his head back" and "I drop it in water and it floats" are unlike. But in Shawnee the corresponding statements are closely similar, emphasizing the fact that analysis of nature and classification of events as like or in the same category (logic) are governed by grammar.

tell about unlike facts," he now reasons: "Facts are unlike to speakers whose language background provides for unlike formulation of them."

Conversely, the English sentences, "The boat is grounded on the beach" and "The boat is manned by picked men," seem to us to be rather similar. Each is about a boat; each tells the relation of the boat to other objects — or that's *our* story. The linguist would point out the parallelism in grammatical pattern thus: "The boat is *x*ed preposition *y*." The logician might turn the linguist's analysis into "*A* is in the state *x* in relation to *y*," and then perhaps into $fA = xRy$. Such symbolic methods lead to fruitful techniques of rational ordering, stimulate our thinking, and bring valuable insights. Yet we should realize that the similarities and contrasts in the original sentences, subsumed under the foregoing formula, are dependent on the choice of mother tongue and that the properties of the tongue are eventually reflected as peculiarities of structure in the fabric of logic or mathematics which we rear.

In the Nootka language of Vancouver Island, the first "boat" statement is *tlih-is-ma;* the second, *lash-tskwiq-ista-ma.* The first is thus I-II-*ma;* the second, III-IV-V-*ma;* and they are quite unlike, for the final *-ma* is only the sign of the third-person indicative. Neither sentence contains any unit of meaning akin to our word "boat" or even "canoe." Part I, in the first sentence, means "moving pointwise," or moving in a way like the suggestion of the outline in Fig. 3, No. 2; hence "traveling in or as a canoe," or an event like one position of such motion. It is not a name for what we should call a "thing," but is more like a vector in physics. Part II means "on the beach"; hence I-II-*ma* means "it is on the beach pointwise as an event of canoe motion," and would normally refer to a boat that has come to land. In the other sentence, part III means "select, pick," and IV means "remainder, result," so that III-IV means "selected." Part V means "in a canoe (boat) as crew." The whole, III-IV-V-*ma*, means either "they are in the boat as a crew of picked men" or "the boat has a crew of picked men." It means that the whole event involving picked ones and boat's crew is in process.

As a hang-over from my education in chemical engineering, I relish an occasional chemical simile. Perhaps readers will catch what I mean when I say that the way the constituents are put together in these sentences of Shawnee and Nootka suggests a chemical compound, whereas their combination in English is more like a mechanical mixture. A mixture, like the mountaineer's potlicker, can be assembled out of almost anything and does not make any sweeping transformation of the overt appearance of the material. A chemical compound, on the other hand, can be put together only out of mutually suited ingredients, and the result may be not merely soup but a crop of crystals or a cloud of smoke. Likewise the typical Shawnee and Nootka combinations appear to work with a vocabulary of terms chosen with a view not so much to the utility of their immediate references as to the ability of the terms to combine suggestively with each other in manifold ways that elicit novel and useful images. This principle of terminology and way of analyzing events would seem to be unknown to the tongues with which we are familiar.

It is the analysis of nature down to a basic vocabulary capable of this sort of evocative recombination which is most distinctive of polysynthetic languages, like Nootka and Shawnee. Their characteristic quality is not, as some linguists have thought, a matter of the tightness or indissolubility of the combinations. The Shawnee term *l'θawa* could probably be said alone but would then mean "it (or something) is forked," a statement which gives little hint of the novel meanings that

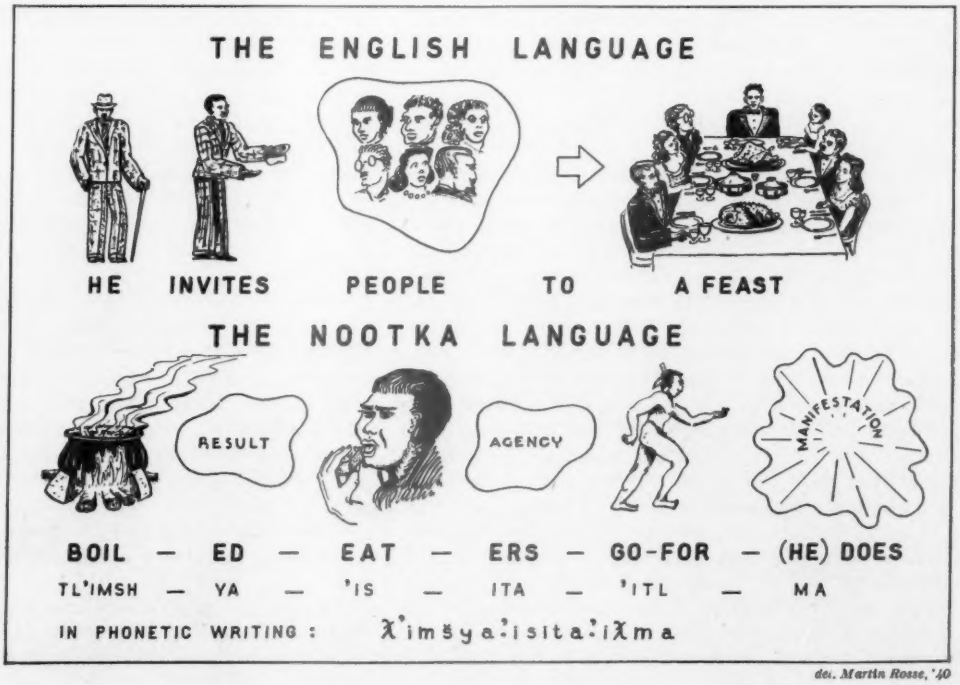

THE ENGLISH LANGUAGE
HE INVITES PEOPLE TO A FEAST
THE NOOTKA LANGUAGE
RESULT
AGENCY
MANIFESTATION
BOIL — ED — EAT — ERS — GO-FOR — (HE) DOES
TL'IMSH — YA — 'IS — ITA — 'ITL — MA
IN PHONETIC WRITING : χ'imšya:'isita:'iχma
dei. Martin Rosse, '40

Fig. 2. Here are shown the different ways in which English and Nootka formulate the same event. The English sentence is divisible into subject and predicate; the Nootka sentence is not, yet it is complete and logical. Furthermore, the Nootka sentence is just one word, consisting of the root tl'imsh *with five suffixes.*

arise out of its combinations — at least to our minds or our type of logic. Shawnee and Nootka do not use the chemical type of synthesis exclusively. They make large use of a more external kind of syntax, which, however, has no basic structural priority. Even our own Indo-European tongues are not wholly devoid of the chemical method, but they seldom make sentences by it, afford little inkling of its possibilities, and give structural priority to another method. It was quite natural, then, that Aristotle should found our traditional logic wholly on this other method.

Let me make another analogy, not with chemistry but with art — art of the pictorial sort. We look at a good still-life painting and seem to see a lustrous porcelain bowl and a downy peach. Yet an analysis that screened out the totality of the picture — as if we were to go over it carefully, looking through a hole cut in a card — would reveal only oddly shaped patches of paint and would not evoke the bowl and fruit. The synthesis presented by the painting is perhaps akin to the chemical type of syntax, and it may point to psychological fundamentals that enter into both art and language. Now the mechanical method in art and language might be typified by Fig. 3, No. 3A. The first element, a field of spots, corresponds to the adjective "spotted," the second corresponds to the noun "cat." By putting them together, we get "spotted cat." Contrast the technique in Fig. 3, No. 3B. Here the figure corresponding to "cat" has only vague meaning by itself — "chevronlike," we might say — while the first element is even vaguer. But combined, these evoke a cylindrical object, like a shaft casting.

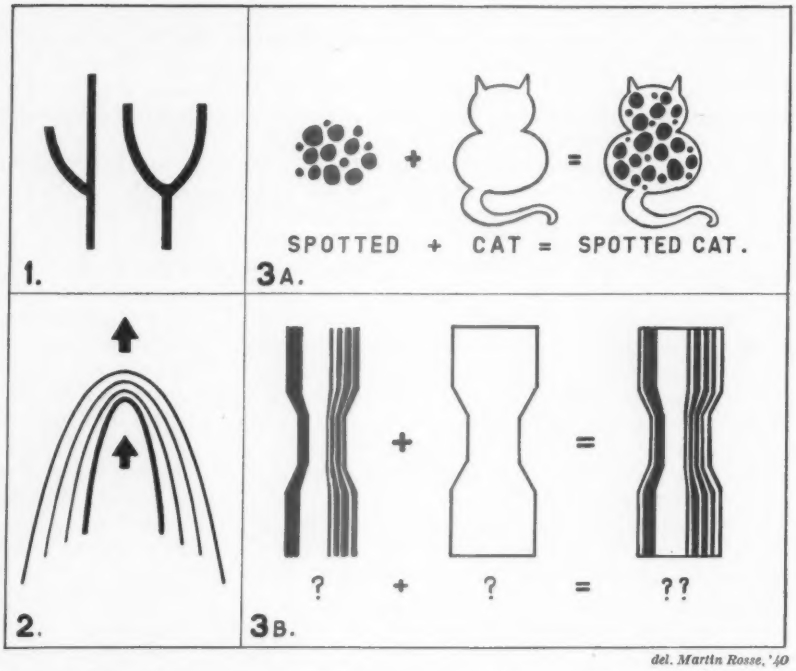


Fig. 3. Suggested above are certain linguistic concepts which, as explained in the text, are not easily definable.

The thing common to both techniques is a systematic synthetic use of pattern, and this is also common to all language techniques. I have put question marks below the elements in Fig. 3, No. 3B, to point out the difficulty of a parallel in English speech and the fact that the method probably has no standing in traditional logic. Yet examination of other languages and the possibility of new types of logic that has been advanced by modern logicians themselves, suggest that this matter may be significant for modern science. New types of logic may help us eventually to understand how it is that electrons, the velocity of light, and other components of the subject matter of physics appear to behave illogically, or that phenomena which flout the sturdy common sense of yesteryear can nevertheless be true. Modern thinkers have long since pointed out that the so-called mechanistic way of thinking has come to an impasse before the great frontier problems of science. To rid ourselves of this way of thinking is exceedingly difficult when we have no linguistic experience of any other and when even our most advanced logicians and mathematicians do not provide any other — and obviously they cannot without the linguistic experience. For the mechanistic way of thinking is perhaps just a type of syntax natural to Mr. Everyman's daily use of the western Indo-European languages, rigidified and intensified by Aristotle and the latter's medieval and modern followers.

As I said in an article, "Science and Linguistics," in The Review for April, 1940, the effortlessness of speech and the subconscious way we picked up that activity in early childhood lead us to regard talking and thinking as wholly straightforward and transparent. We naturally feel that they embody self-evident laws of thought, the same for all men. We know all the answers! But when scrutinized, they become dusty answers. We use speech for reaching agreements about subject matter: I say, "Please shut the door," and my hearer and I agree that "the door" refers to a certain part of our environment and that I want a certain result produced. Our explanations of how we reached this understanding, though quite satisfactory on the everyday social plane, are merely more agreements (statements) about the same subject matter (door, and so on), more and more amplified by statements about the social and personal needs that impel us to communicate. There are here no laws of thought. Yet the structural regularities of our sentences enable us to sense that laws are *somewhere* in the background. Clearly, explanations of understanding such as "And so I ups and says to him, says I; see here, why don't you . . . !" evade the true process by which "he" and "I" are in communication. Likewise psychological-social descriptions of the social and emotional needs that impel people (*Continued on page 266*)

Glassy Geometry

How the Properties of Glass Depend on Atomic Arrangement; Research Finds Ways to Correlate the Two

By Bertram E. Warren

On the ways in which atoms hang onto each other depends everything that man does, not to speak of man himself, for which reason distinct interest invests the inquiries which science makes into the structure of matter. Often, however, these investigations appear so remote from immediate or practical concerns that the observer very easily misses the connection between a research and the make-up of his own frame. Often, moreover, because atoms are so bafflingly small and so deceptively elusive, the structure of matter in certain of its forms seems a question bound to remain virtually unanswered. Few problems can be conjured up which will offer greater difficulty, at first thought, than that of determining how the atoms are fastened together in a tiny crystal, as in a lump of rock salt or in a diamond. Yet this state of matter — the crystalline solid — is really so orderly and neat that it presents a comparatively easy task to the unraveler.

In a crystal, atoms of the elements making up the material are packed in a standard pattern, repeated over and over. Determine that pattern once, and the structure of the substance is clear. The process of making the first determination may be extremely difficult, but the difficulty is that involved in interpreting relations which, after all, are regular, however complicated they may be.

To unravel the systems by which atoms are assembled, the investigator has as his principal means the x-ray diffraction technique described in The Review for February (page 172), as it is used in studies of internal stresses in metals. The method, it will be recalled, takes advantage of the fact that x-rays impinging on a substance are bounced back from it, or diffracted, at angles dependent upon the distances separating the atoms composing the sample. Rebounding in this fashion, the x-rays produce on a photographic film ringlike patterns of lines (Fig. 1, page 254). From these, by mathematical analysis, arrangement of atoms in the specimen may be ascertained. Naturally, the more complex is the structure of the substance bombarded — the greater the number and kinds of atoms composing it, the more intricate the configuration in which they are packed — the more difficult it is to perform the mathematical operations necessary for interpretation of the photographs. If the structure is crystalline, the photograph will show good detail and can be interpreted by a comparatively simple technique. Amorphous structure, as in a liquid, however, gives a less detailed picture and makes interpretation difficult.

Here are reasons why our knowledge of the liquid state of matter is so scanty as to be practically negligible in comparison with our knowledge of the crystalline state: The atoms or molecules constituting matter in the liquid state are in a random arrangement, lacking the regularity of structure characteristic of the crystal. The x-ray diffraction patterns which liquids produce consist of broad rings with fuzzy edges. From these, the best knowledge obtainable concerns the distribution of neighboring atoms or molecules about any one molecule in the sample; the infinitesimal census cannot be extended over a long range by means of a regularly repeating pattern as is true in analysis of crystalline matter.

The difficulty here described makes particularly important the analysis of the structure of glass, for glass as an amorphous solid is a sort of halfway station between the neatly repetitive patterns of crystalline solid matter and the almost perverse indeterminacy of amorphous liquid matter. Water, for example, changes from amorphousness to crystallinity when it freezes into ice. Glass, which starts out as a collection of bits of crystalline matter — silica, soda, and so on — passes through a stage of being amorphous liquid matter as it is melted and fined in the pot, and then becomes what may be called an undercooled liquid — an amorphous solid. The atoms originally bonded into the orderly crystalline structure of the ingredients in the batch are still present in the unsymmetrical structure of the finished product. But the orderly system of bonding which held some of them together in the silica crystals, for instance, was disrupted when the heat of the melting pot increased the temperature vibration of each atom to a point beyond the strength of the forces of attraction which had held the atom in bond relationship with its neighbors. A new configuration came into being as the melt was cooled into glass — one is schematically shown in Fig. 2, page 255 — but it was chaotic as compared with the orderliness in the original ingredients.

The geometry of this new configuration — the relations of distance and number involved in the assembly of atoms and ions (electrified particles formed through the gain or loss of electrons by neutral atoms or groups of atoms) — though it lacks the regularity of the geometry of crystalline matter, is of equal significance as a means of correlating and explaining the properties of the glass. Many of the chemical and physical properties of crystalline solids are known to result from the geometrical relations of the atoms and ions constituting them. The properties of amorphous solids — for instance, the fact that a glass has no definite melting point — may be explained similarly in terms of geometry, once the geometry has been established by the techniques which have been mentioned.

Through x-ray diffraction studies at the Institute during the past five years, a fairly definite idea of the geometrical structure of glass has been attained. Research which is now in process is aimed at correlating properties with that geometry in order to explain them. Two related problems in the properties of glass, it has been found, can be interpreted in terms of purely geometrical considerations. The first problem is that of immiscibility of glass melts; the second, that of the anomalous effects of boric oxide in glass.

Immiscibility is a phenomenon familiar enough; mix a cocktail and one need not worry about whether the ingredients will blend; mix a French dressing, and the oil and vinegar, however well shaken together, remain separate entities. The first combination is miscible; the second, immiscible. Perhaps it is appropriate that the glass of the cocktail shaker or the dressing cruet should offer an answer to the question of why some things mix and others don't. Glass made of soda and silica resembles the cocktail; in a soda-silica melt there is complete miscibility over the whole range of composition.

Lime-silica glass resembles the French dressing in some measure, for when the lime content is low, such a melt will segregate at certain temperatures into two phases which are immiscible. Whether immiscibility is a good or a bad thing depends upon the purpose for which the batch of glass is designed. The opacity, for instance, which results from immiscibility, may be desired for some uses. The important matter is to find out why a batch separates into two liquids, as in the French dressing, and to find out proportions of ingredients and temperatures of operation which will control the batch and prevent the phenomenon. Since the making of glass was for years more an art than a science, the question of the cause of immiscibility has only in our own time been attacked from the point of view of atomic relations.

To see how the geometry of the lime-silica combination explains why a batch of given proportions will, at a certain temperature, follow the example of the salad dressing rather than the cocktail, consideration of the structure of a soda-silica glass will be useful. The soda-silica combination, it will be remembered, remains miscible throughout. In that combination, each silicon atom is bonded to four oxygen atoms in such a way that the oxygens occupy the four corners of a tetrahedron, in the center of which is the silicon, like this ⟶

Every oxygen atom in the mixture is bonded to at least one silicon atom. But, because the ingredients of the batch are sodium oxide (Na_2O) and silicon dioxide (SiO_2), the number of oxygen atoms in the mixture is more than twice the number of silicons, and as a result some oxygen atoms are bonded to only one silicon. The sodium in the mixture is in the form of positive ions which have lost one electron and which are distributed at random in the holes of the oxygen-silicon network, each sodium in contact with about six oxygens. Figure 2 shows an idealized horizontal slice through this structure; because the figure is in two dimensions only, it shows the silicons bonded to only three oxygens, the fourth being in the third-dimensional plane either above or below the silicon, and hence not represented. The figure indicates that each atom is bonded to its neighbors in a fairly definite way, but that the scheme of structure is so flexible that it is not necessary for any unit of structure to repeat itself at regular intervals as in a crystal. Such flexibility of configuration is the essential difference between a glass and a crystalline solid.

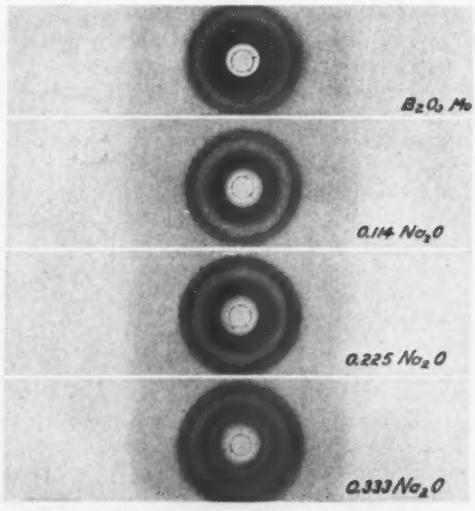
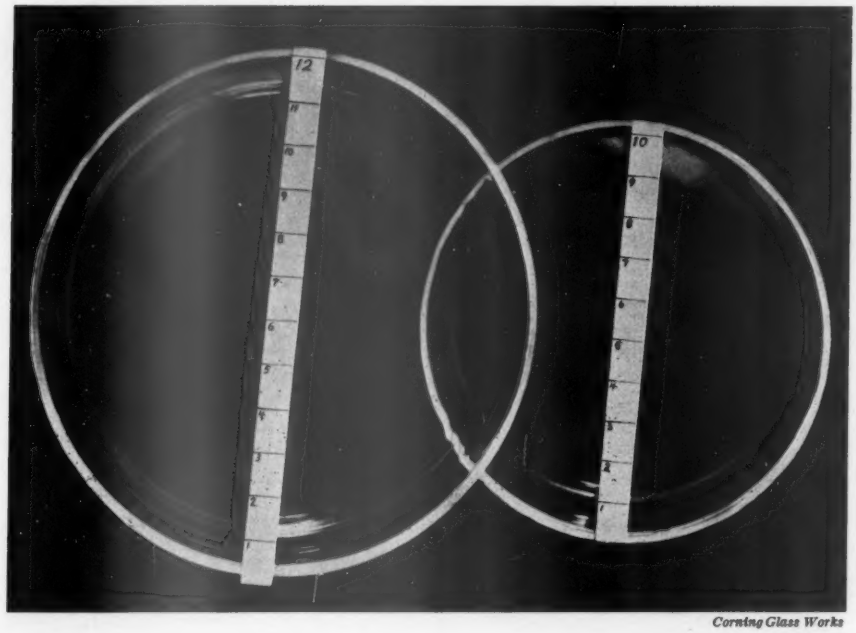


Fig. 1. X-ray patterns of soda–boric-oxide glass

Now in a lime-silica melt of relatively low lime content, the structure is essentially the same as that which has been described. The positive sodium ions are replaced, of course, by positive calcium ions. The calcium ions have lost two electrons as against the one lost by the sodium ions. The number of oxygen atoms in the mixture is again more than twice the number of silicon atoms, since the ingredients are calcium oxide (CaO) and silicon dioxide (SiO_2). As in the soda-silica melt discussed above, the silicon atoms strive to keep themselves constantly bonded to four oxygens, and the more oxygens there are available, the easier it is for the silicons to do so. The strong bonding of the silicons to all available oxygens tends to hold the melt together in a single phase, corresponding to the blending of the ingredients of the cocktail. But another effect occurs which works in the opposite direction.

Those oxygens which are bonded to but one silicon — of which there are quite a number because of the proportions of the ingredients of the batch — are unsaturated; that is, their electrostatic attractive forces are not exhausted by the job of hanging onto a silicon atom. They hence have some unused force, which tends to pull toward them the calcium ions which are wandering around in the melt. The calcium ions, it will be remembered, have lost two electrons, and they are for this reason considerably less docile than the sodium ions of the soda-silica combination which has been discussed. The calciums seek to get into surroundings which will stabilize them — surroundings consisting of six unsaturated oxygen atoms. Each unsaturated oxygen must be in contact with more than one calcium for stabilization, however, since the number of unsaturated oxygens is only double the number of calciums. Unless



Shallow dishes made of "preformed" glass. That on the right was, before an acid- and heat-treating process, the same diameter as that on the left. After the shrinkage, the glass consists of about 96 per cent silica and 4 per cent boric oxide and has many of the good qualities of fused silica without the expense and difficulty of direct manufacture from silica.

Corning Glass Works

the geometrical relations of the system of calcium, oxygen, and silica are such that the necessities of the calcium ions and the unexhausted attractive powers of the unsaturated oxygen atoms can be satisfied within the single phase — that is, the cocktail — there will be trouble. The unsaturated oxygens — potential two-timers — and the philandering calcium ions will, if they can't be accommodated in orderly society, go off by themselves and set up a polygamous regime of their own. The result in terms of the glass melt will be separation of the liquid material into two immiscible phases, one of which, at about 1,700 degrees centigrade, will be almost pure silica; the other will be about 28 per cent calcium and the rest silica.

For control of this situation the question of importance is obvious: What geometrical arrangement of atoms will permit calcium ions to be surrounded by six unsaturated oxygens and will permit the unsaturated oxygens to remain bonded to silicons as well? The answer is principally a matter of the volume of glass available to each calcium ion, or the reverse, a matter of the percentage of calcium in the batch. Calcium ions have to share among themselves the unsaturated oxygens; hence the distribution of calcium ions must be conditioned by the distances which this necessity permits between them.

Obviously, two calcium ions which are in contact with the same oxygen cannot be farther apart than twice the sum of the calcium and oxygen radii, a distance which figures out as 4.76 angstrom units. If we start with this calcium-to-calcium distance, we can reckon that in a random distribution of atoms, the volume of glass per calcium will be of the order of the cube of the linear separation, or 108 cubic angstroms of glass for each calcium. Such a volume is produced by a batch containing 33 per cent of calcium. Enough unsaturated oxygens will be present to surround the calcium ions properly and yet maintain their bonds with silicon atoms. In short, the calcium content will be high enough for the calcium ions and the single-bonded oxygen atoms to be satisfactorily close to each other, and stability will result. If the calcium content is less than 33 per cent, for the temperature conditions assumed in this example (1,700 degrees centigrade); the calcium ions cannot collect about themselves the desired number of oxygens within the available volume of glass, and the separation into two liquids will follow. At higher temperatures, a lower calcium content will be sufficient for miscibility.

The matter of immiscibility, then, boils down to the fact that when the geometry of distribution of atoms will not allow satisfaction of the requirements of the atoms, a new distribution results. In a sense, the situation resembles packing bricks and cork stoppers in a barrel of water — if there are bricks enough, the corks can be kept under water; if there are not enough bricks to make a network holding the corks under, a new distribution will occur. (*Continued on page 273*)

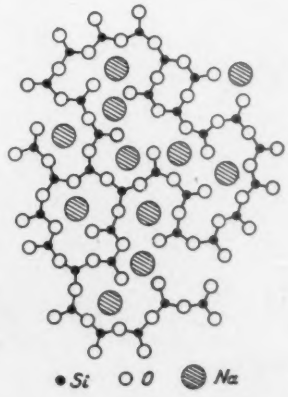


Fig. 2. Schematic representation in two dimensions of the structure of soda-silica glass. To correspond to two dimensions, the silicons are shown bonded to three oxygens rather than to four. Each silicon atom is actually linked to four oxygens, the fourth being directly above or below the silicon and therefore not shown.

"Patternes and Samples"

Chicago's Museum of Science and Industry Expresses the Teaching Function of Such Institutions—an Idea Implicit in Earliest Proposals for Museums

By A. C. Carlton

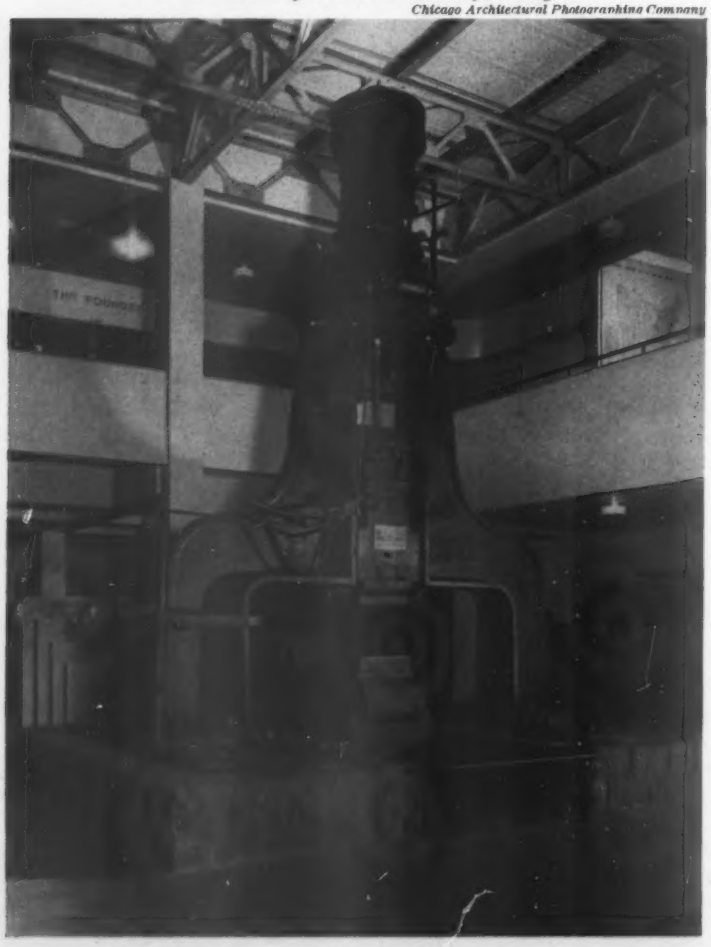
SCIENCE Discerns the Laws of Nature—Industry Applies Them to the Needs of Man. Thus reads the inscription on the walls of the rotunda of the Museum of Science and Industry in Jackson Park, Chicago, defining the scope and underlying purpose of that teaching institution.

Scientific and industrial museums were not originally conceived by this generation nor by those immediately preceding it. Francis Bacon's *New Atlantis*, first published in 1627, included in his utopia: "For our Ordinances and Rites: Wee have two very Long, and Faire Galleries: In one of these wee place Patternes and Samples of all manner of the more Rare and Excellent Inventions: In the other wee place the Statua's of all Principall Inventours. . . ."

René Descartes (1596–1650) suggested a collection for the instruction of artisans. Almost two centuries later, at the time of the French Revolution, a decree was passed authorizing the formation of the Conservatoire des Arts et Métiers, wherein machines, models, tools, drawings, and so forth should be deposited, and the construction and uses of these tools and machines should be explained. The *conservatoire* was established in the sequestered priory of St. Martin des Champs, and this, the oldest of the industrial museums, has remained there to this day. It is, and always has been, an adjunct to the École Centrale des Arts et Manufactures and is used principally by that school.

In London, the science museum owes its founding to the Great Exhibition of all Nations of 1851. Temporary buildings in South Kensington housed the first collection in 1853, and since that time this museum has continued to expand both in scope and in the extent of its collections. South Kensington was the first to display operating exhibits.

This Nasmyth steam hammer, reputed to be the first used in America, is displayed in the Museum of Science and Industry, Chicago.
Chicago Architectural Photographing Company



Oskar von Miller, beginning in 1903, conceived, planned, and operated in Munich for many years Das Deutsches Museum von Meisterwerken der Naturwissenschaft und Technik, Europe's foremost scientific and industrial museum. Von Miller, a distinguished electrical engineer, revolutionized the technique of the teaching museum and contributed more than any other person toward the development of industrial museums. Shortly after the founding of the Deutsches museum, Das Technische Museum für Industrie und Gewerbe was organized in Vienna and patterned after its more famous progenitor.

All of this early development occurred in Europe, curiously enough, and the United States, the world's leading industrial nation, had no part. The anomaly no longer exists, however, as there are now in this country three museums comparable with the leading European institutions. They are the New York Museum of Science and Industry; the Franklin Institute, Philadelphia; and the Museum of Science and Industry, Chicago. All have slightly different philosophies, but all have as a fundamental aim the teaching of scientific principles and their industrial applications. American museum officials have learned much from European museums at Munich and elsewhere but are not slavishly following them. Rather are the Americans profiting by Europe's experience.

Julius Rosenwald, Chicago philanthropist, was greatly interested in von Miller's Deutsches museum, which he visited in Europe some years ago. He returned to Chicago imbued with the desire to make possible a similar institution in this country. After considerable thought he expressed his hopes before the Commercial Club of Chicago. The members were heartily in favor of the project, and Mr. Rosenwald made available $1,000,000 to be used in studying European museums and in planning the Chicago institution. Visits to the Munich museum and others followed; Dr. von Miller and his associates went to Chicago, and all agreed that an institution of the magnitude visualized needed far more money than that originally provided. Mr. Rosenwald contributed an additional sum of $2,000,000.

Chicago Architectural Photographing Company

A group of visitors watch a coal-loading machine at work in the museum's coal mine.

Meanwhile, the beautiful art palace of the World's Columbian Exposition of 1893, being of temporary construction, was rapidly falling to ruin. Interest of public-spirited citizens resulted, in 1924, in the floating of a bond issue of $5,000,000 to reconstruct the building, using permanent materials — exterior walls of Indiana limestone, roof of copper, and so forth. No definite decision was made about the use to which the building would be put, as the activating motive was primarily the preservation of a beautiful monument. Later it was discovered that $5,000,000 would not suffice to complete the restoration. Mr. Rosenwald then offered to contribute the difference between the total cost and the amount of the bond issue, provided the building were used exclusively to house an industrial museum. His offer was accepted, and the reconstruction of the building began in 1929. Exterior construction was completed in 1931, and a small section (40,000 square feet) of the interior was partly finished to permit occupancy in 1933. This section was used from July, 1933, to March, 1938, for the display of exhibits, including a full-size, operating coal mine. In 1936 a contract for the completion of the interior was let, and another section of the building, the west pavilion, likewise with a floor area of approximately 40,000 square feet, was completed, filled with displays, and opened to the public in March, 1938. The section which had been occupied during the preceding five years was then cleared of exhibits and turned over to the building contractor for finishing. The interior of the entire building was completed in December, 1938. Since that time installation of exhibits has been in progress.

The total attendance in these temporary areas for the period from July, 1933, to October 26, 1940, was 3,134,838. On the latter day the main central section was opened to the public, and the attendance figures from that date to the end of 1940 reached 141,482.

The primary purpose in opening part of the building prior to the completion of the entire structure was to confirm or disprove theories as to what constitutes interesting and instructive exhibit material. Exhibits were modified in many instances and replaced by other types of material at rather frequent intervals. Meanwhile, detailed studies of visitors' reactions were made. In other words this space served as a proving ground to guide in the planning of the finished museum.

The museum building consists of a central pavilion (500 feet by 300 feet), two wing pavilions (each 210 feet by 130 feet), and galleries connecting the wings to the central pavilion. A dome surmounts each of the three pavilions. The ground area is 263,000 square feet, considerably larger than the Capitol at Washington, and the over-all length from east to west is almost a quarter of a mile.

The total floor area of the building is roughly 600,000 square feet, of which two-thirds is allocated to exhibits. The remaining third contains an auditorium (seating 1,000), a large lecture room (seating 300), a number of small lecture rooms, library facilities (including reading rooms for adults and children and stack space for 170,000 volumes), cafeteria, staff dining room, children's lunchroom, kitchens, offices, laboratories, shops, studios, and all service facilities.

The focus of interest from the architectural point of view is the rotunda under the dome of the central pavilion. The rotunda is 80 feet in diameter and rises 120 feet to the under surface of the dome, which is supported by four huge piers faced with white marble. Radiating from the rotunda in the four cardinal directions are great

halls 90 feet wide and 65 feet high. The east and west halls are 210 feet long, and the north and south halls, 120 feet.

The architectural style is based on Greek Classic applied to a modern plan. The 276 Ionic columns, the doorways, and the exterior ornamental moldings were copied from those on the Erechtheum, as were the twenty-four caryatids. Each of the latter is thirteen feet high and weighs six tons. Frieze and metope panels of the Parthenon were reproduced in actual size. The interior is not incompatible with the Classical exterior, the plan is flexible, all necessary facilities are provided in abundance, the great halls are dignified and impressive, and the rotunda is inspiring.

The ten acres of floor space contain exhibits covering the physical sciences, and all important industries have been arbitrarily divided into nine departments. These departments, with some of their more interesting and important exhibits, are as follows:

(1) *Physics.* Stroboscopic-light demonstration; high-frequency induction demonstration; whispering gallery; binaural-hearing demonstration; operating exhibits explaining Newton's three laws of motion and Cavendish's experiment for measuring the gravitational constant.

(2) *Chemistry.* Periodic table of the chemical elements in a beautiful setting at the center of the main rotunda; full-scale alchemist's laboratory and modern laboratory alcoves; operating exhibits explaining chemical laws and reactions.

(3) *Fuels and Metals.* This department will be discussed at some length in subsequent paragraphs.

(4) *Agriculture, Forestry, and Textiles.* Machines and models illustrating historical development of agricultural machinery; spinning and weaving demonstration; termite colony with hundreds of the insects at work under glass; woodworking machinery in operation.

(5) *Power.* Corliss engine (1893) in operation; demonstration of man-made lightning with a million volt surge generator; series of models of mechanical motions; diorama (sixty-five feet long) showing generation, transmission, and utilization of electric power.

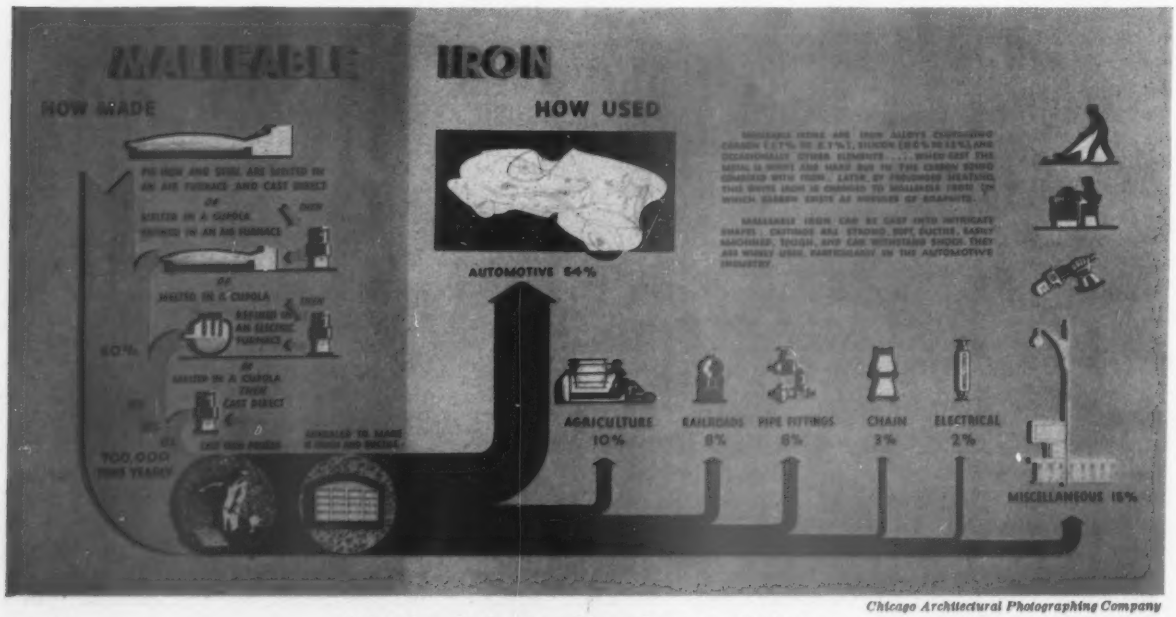
(6) *Transportation.* Historical airplanes suspended from the ceiling of the east hall; driving gear and steam-distribution system of a modern locomotive (operating); demonstration of antiknock testing of motor fuels; demonstration of steel being cut under water; a huge model railroad with full-size controls.

(7) *Graphic Arts.* Modern rotary press on which will be printed the museum newspaper; modern job-printing shop in which letterpress operations are demonstrated; offset lithographing press in operation.

(8) *Engineering Construction.* Model of the Parthenon; original structural bay of the Home Insurance Building, the first skyscraper, partly stripped to show skeleton construction; operating diorama of the Pennsylvania Railroad Company's vertical-lift bridge over the Chicago River, equipped with spot lighting and recorded lecture; pit lined with several types of sheet piling in which pile driving and electric-shovel operations are demonstrated with small machines.

(9) *Medical Sciences.* The transparent woman; embryos and anatomical sections; historical pharmacist's shop; series of dioramas showing development of surgery.

This list, it is believed, will indicate the general character and scope of the museum. Visitors are, of course, privileged to spend their time at the museum as they see fit. The more serious-minded persons — those who wish to gain a well-balanced co-ordinated picture of the sciences and their industrial applications — are encouraged to visit the museum many times. An underlying purpose of the institution is the depiction of the Machine Age and the steps that led to that age. First, then, the serious-minded person (*Continued on page 274*)



Chicago Architectural Photographing Company

A flow chart showing the making and uses of malleable iron

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Charles E. Locke, '96, who becomes professor emeritus, will continue as alumni secretary.

Professors Emeriti

THIS year brings the retirement of eight members of the Faculty who have been closely associated with the growth of the Institute and whose influence as teachers will long be remembered by thousands of former students. They are Professor Charles E. Locke, '96, a member of the Institute's staff for forty years; Professor Charles E. Fuller, '92, who will be remembered by every student in the Department of Mechanical Engineering since 1892, when he joined the staff; Professor George Owen, '94, internationally known yacht designer, who joined the faculty of the Department of Naval Architecture and Marine Engineering in 1915; Professor Arthur A. Blanchard, '98, who came to the Department of Chemistry in 1899; Professor Ralph R. Lawrence, '95, who was appointed to the Department of Physics in 1896 and was transferred to the Department of Electrical Engineering in 1901; Professor Joseph C. Riley, '98, a member of the staff of the Department of Mechanical Engineering since 1898; Professor Archer T. Robinson, whose admirable qualities as a teacher have enriched the influence of the Department of English and History for many years; and Professor Edward E. Bugbee, '00, who, except for an interval between 1903 and 1907, has been a member of the staff of the Department of Mining and Metallurgy since 1900. All will retire with the rank of professor emeritus. Professor Locke and Professor Fuller have been appointed honorary lecturers in their Departments, and Professor Locke will also continue as secretary of the Alumni Association. The retirement of Professor Bugbee, who has been on leave of absence for the past year, will not become effective until next October, while Professor Riley will not retire until January.

Wherever mining engineers are found, from Alaska to the Andes and west to the African gold fields, Charlie Locke is known both as an admirable teacher and as an engineer who has contributed much to the knowledge of ore dressing, a field in which he was long associated with Professor Robert H. Richards, '68. Professor Locke became acting head of the Department of Mining Engineering upon the retirement of Professor W. Spencer Hutchinson, '92, in 1939 and joined the staff of the Department of Metallurgy last year when Mining was discontinued as a Course. Professor Locke's professional connection with the Institute began as an assistant to Professor Richards in the preparation of the latter's widely known textbook on ore dressing. He was appointed an instructor in 1901 and advanced to the rank of professor in 1930. During those fruitful years under the guidance of Professor Richards, he gradually took over the teaching burden in mining engineering and ore dressing. For years Professor Locke has made it a practice to travel during the summer months in order to keep in close touch with the practical operations of mining. There are few mines in the United States, Canada, and Newfoundland which have not been surveyed by his critical eye. His professional activities have in no sense exhausted his capacity for various other activities, for Charlie Locke is known to every Alumnus of the Institute as the energetic and very loyal secretary of the Alumni Association, a post to which he was appointed in 1930. He has been equally active in the affairs of the Class of 1896 and has been its Secretary for thirty-three years.

It is a pleasure to be able to announce that Professor Locke's association with the Institute does not end with his retirement. His appointment as honorary lecturer in the Department of Metallurgy and his continuing daily duties as secretary of the Alumni Association assure his colleagues of the stimulation of his presence with his constant companion, a colossal and historic pipe, which more than once has violated the standards of smoke-abatement engineers.

Professor Fuller has been dean of army students since 1933 and was for eighteen years in charge of the Testing Materials Laboratory. As chairman of the committee in charge of graduate courses in his Department, he has had much to do with the advanced studies in Mechanical Engineering. Professor Fuller has long been interested in the design and construction of ordnance and has

devoted part of his time to this specialized field of engineering. In 1923 he was commissioned colonel in the ordnance department of the Officers' Reserve Corps of the United States Army. As a technical author, Professor Fuller collaborated with his classmate W. A. Johnston in the preparation of a textbook on applied mechanics, and he has written many reports of investigations into mechanical engineering projects. During the past thirty years he has been actively interested in the development of the public utilities of the town of Wellesley, Mass., of which he has for many years been a resident.

Professor Owen, whose name as a designer of ships is known to every yachtsman in the country, began his career as a textile mill engineer, following his graduation from Technology in 1894. Later he became an inspector of ordnance, after having been associated with the Herreshoff Manufacturing Company in Rhode Island. In 1901, while serving as an engineer in a steel plant in Hamilton, Ontario, Professor Owen first found the opportunity to indulge his interest in boats. He then joined the engineering staff of the Fore River Shipbuilding Company and in 1907 began an independent career as shipbuilder and designer. In 1915 he was appointed to the Faculty of the Institute as an assistant professor. During his career he has designed a number of famous racing yachts and has done notable work as well in the field of merchant ship design. In his teaching Professor Owen has translated and passed on to his many students not only the formal knowledge of naval architecture but a rich store of information gathered in many years of experience in seamanship and the operation of vessels of various types.

Professor Blanchard is distinguished not only as a very able teacher but as an eminent research worker and author of several important technical books. He bears the name of one of New England's oldest families, is a native of Boston, and began his education in the schools of Newton, from which he came to Technology. Upon his graduation in 1898 he became an assistant in the Department of Chemistry, an association which was interrupted two years later when he was awarded a fellowship for study at the University of Leipzig, where he was awarded the degree of doctor of philosophy in 1902. Returning to this country, he served for a time as an instructor at New Hampshire College, now the University of New Hampshire, before rejoining the staff of the Institute. His broad interests in research have included investigation of migration ratios, the decomposition of ammonium nitrate, the viscosity of solutions in relation to the constitution of dissolved substances, atomic structure and valence, and the carbonyls of metals. In collaboration with Professor Joseph W. Phelan, '94, Dr. Blanchard wrote *Synthetic Inorganic Chemistry* and also he was joint author with Frank B. Wade of a textbook, *Foundations of Chemistry*. Another work in which he collaborated was *The Electrolytic Dissociation Theory*, written with Henry P. Talbot.

Professor Lawrence, a brother of William H. Lawrence, '91, Professor Emeritus of Architectural Engineering, is an authority on alternating current and alternating current machinery and is the author of two textbooks, *Principles of Alternating Current Machinery* and *Principles of Alternating Currents*. After he was graduated as an electrical engineer in 1895, Professor Lawrence joined the Department of Physics as an assistant and two years later was appointed an instructor. In 1901 he was transferred to the Department of Electrical Engineering, in which he has served ever since. He has been active in the leading engineering societies, and he is a fellow of the American Institute of Electrical Engineers, a member of the American Academy of Arts and Sciences, the Society of American Military Engineers, the Illuminating Engineering Society, and the Society for the Promotion of Engineering Education.

Professor Riley, who, during the World War, served as a major in the Air Service, has been a member of the staff of the Institute since his graduation in 1898. Beginning as an assistant, he advanced in subsequent promotions to the rank of professor of heat engineering in 1920.

Professor Robinson, who joined the Department of English in 1896 and has long been in charge of its courses in history, was educated at Phillips Academy, Andover, and at Harvard University, where he was awarded his bachelor's degree in arts in 1896 and his master's degree in 1915. As a student of European history, he has traveled widely and done much careful research to enrich the substance of his well-remembered courses. As chairman of the Cilley Fund, established to provide books for the Cilley Library in Walker Memorial, Professor Robinson has been influential in increasing the range of the library both for recreational reading and as a fruitful source of material for courses in his Department. He is the author of *Applications of Logic*, published in 1912, and of *Notes and Outlines*, in 1922.

Professor Bugbee is well known as an authority on fire assaying. A native of Brookline, Mass., he was educated in the public schools there and was graduated from the Institute in 1900. In addition to his teaching experience at Technology, he also served as an assistant professor of mining and metallurgy at Iowa State College, as well as at the University of Washington, from which he returned to the Institute. During 1901–1902 he was on the technical staff of the Brookfield Mining Company and later was an assistant metallurgist for the United States Geological Survey. During 1918 he served as assistant educational director of the committee on education and special training for the United States War Department. He is the author of *A Textbook of Fire Assaying* and is a member of the American Institute of Mining and Metallurgical Engineers, Sigma Xi, and Beta Theta Pi.

Promotions and Appointments

APPOINTMENT of Sverre Petterssen to head the new Department of Meteorology is announced in the Institute's list of staff promotions and appointments for the next academic year. Also announced is the appointment of two new members to the faculty of the Department of Biology and Public Health. Dr. Petterssen, who since 1939 has been acting head of the Course in Meteorology, which now becomes a separate Department, will succeed Professor Carl-G. A. Rossby, who has been on an extended leave of absence to be assistant chief of the United States Weather Bureau, in

Courtesy of the Christian Science Monitor

Training in the engineering aspects of war as part of the nation's defense program is being given to some 900 young men in four of Greater Boston's colleges. Much work is done at the Institute, where this photograph shows (left to right) three members of the special defense staff: George Eggleston, assistant in naval architecture; Jere R. Daniell, '97, supervisor of naval architecture and marine engineering; and Raymond E. Keyes, '40, assistant in marine engineering; with two members of the Institute Faculty: Raymond D. Douglass, '31, Professor of Mathematics; and Arthur L. Townsend, '13, Associate Professor of Mechanical Engineering. Professors Douglass and Townsend are associated with the Engineering Defense Training Bureau of Metropolitan Boston, with headquarters at Technology. Edward L. Moreland, '07, Dean of Engineering at the Institute, is regional adviser.

charge of research. Professor Rossby will resign to join the faculty of the University of Chicago.

Faculty members promoted to the rank of professor include Hoyt C. Hottel, '24, Thomas K. Sherwood, '24, and Harold C. Weber, '18, all of the Department of Chemical Engineering; Ernest H. Huntress, '20, Department of Chemistry; and Julius A. Stratton, '23, Department of Physics.

Members of the Faculty advanced to the rank of associate professor are Samuel C. Collins, Arthur R. Davis, Gerhard Dietrichson, Robert C. Hockett, Nicholas A. Milas, and Charles M. Wareham, '16, all of the Department of Chemistry; and Robert S. Harris, '28, and Marshall W. Jennison, '27, of the Department of Biology and Public Health.

Appointed to the rank of assistant professor are Joseph A. Bergantz, '39, Department of Chemical Engineering; Alfred H. Clifford, Department of Mathematics; Lyman M. Dawes, '23, Arthur E. Fitzgerald, '31, and James E. Mulligan, '33, Department of Electrical Engineering; Albert G. Dietz, '32, Department of Building Engineering and Construction; John A. Hrones, '34, Department of Mechanical Engineering; Walter McKay, '34, of the Department of Aeronautical Engineering; Charles A. Myers, Department of Economics and Social Science; Charles H. Norris, '32, and Herman J. Shea, '33, of the Department of Civil Engineering; and Walter F. Urbach, of the Department of English and History.

Appointments to the grade of instructor include those of Walter K. Bodger, '40, Louis F. Coffin, Jr., Kenneth R. Fox, '40, and Frank J. Mehringer, Department of Mechanical Engineering: and Robert Plunkett, '39, Department of Electrical Engineering.

The two new members of the faculty of the Department of Biology and Public Health, both of whom will be active in the Institute's program in biological engineering, are Richard S. Bear of the department of chemistry of Iowa State College, and David Floyd Waugh of the department of zoology of Washington University in St. Louis. Dr. Bear, who is thirty-two years old and a native of Miamisburg, Ohio, was graduated from Princeton University in 1930 with the degree of bachelor of science. His graduate work was carried on at the University of California, where in 1933 he was awarded the doctorate in philosophy. He then returned to Princeton as a National Research Council Fellow in Chemistry for a year of postdoctorate study. His professional experience includes four years in the zoology department of Washington University, during which time he specialized in the application of physical and chemical methods in the study of nerve structure and physiology. Since 1938 he has been assistant professor in the plant chemistry subsection of the department of chemistry at Iowa State College.

Mr. Waugh is a native of St. Louis and began his early education in England, coming later to St. Joseph Junior College, which he entered in 1931. He studied at Washington University during 1932–1933, at the University of Missouri the following year, and returned in 1934 to Washington University, where he will have completed his work for the degree of doctor of philosophy in June. He was an assistant in zoology from 1936 to 1938 and has been an instructor there since 1939. During the summer of that year he was research assistant to Irving Langmuir in the research laboratories of the General Electric Company. Dr. Bear and Mr. Waugh will begin their work at the Institute next September.

Before coming to the Institute from Norway, of which country he is a native, Dr. Petterssen, the new Head of the Institute's Department of Meteorology, was for seven years in charge of the Weather Forecasting Institute in Bergen, a position to which he was appointed after long experience as a meteorologist in the Norwegian Weather Forecasting Service. Joining the staff as an associate professor in 1939, he was promoted to professor last year.

Dr. Petterssen was graduated from Oslo University with the degree of master of science in 1926 and was awarded his doctorate in science in 1933. He has been a visiting lecturer and instructor at the United States Navy bases in Norfolk and San Diego, as well as at the California Institute of Technology, the United States Weather Bureau in Washington, and the Meteorological Office in Toronto, Canada. He is internationally known as an authority on meteorology and forecasting (subject of his article in this issue of The Review), having developed several methods for quantitative forecasting based on the movement of air fronts, air masses, and low-pressure centers. He has had an important part in guiding the work of his staff in a co-operative research program with the United States Weather Bureau.

Allyne L. Merrill, 1864–1941

ALLYNE L. MERRILL, '85, Professor Emeritus of Mechanism, who was a member of Technology's instructing staff for nearly half a century and secretary of the Faculty for twenty-eight years prior to his retirement in 1934, died in Portland, Maine, on February 26.

Professor Merrill was born in Malden, Mass., in 1864, the son of George S. and Myra H. Litchfield Merrill. He became an assistant in the mechanical engineering laboratories of the Institute in 1885 and was promoted to the grade of instructor in mechanical engineering in 1887. He was made an assistant professor in 1891, associate professor in 1899, and full professor in 1905. In 1906 he was elected secretary of the Faculty. He was the author of *Elements of Mechanism*, published in 1904.

Professor Merrill's popularity among his associates at the Institute was demonstrated at the time of the announcement of his retirement, when nearly 200 of the Faculty attended a luncheon in his honor.

Boston Alumni Meeting

INSTITUTE Alumni of Greater Boston held their second annual midwinter dinner meeting in Walker Memorial on February 27. Nearly 400 Technology men heard Dr. Compton report on the Institute's active co-operation in the national defense program, through research, through special training courses, and through co-operation of members of the staff with various governmental agencies in Washington. Thus the Institute is performing a broad public service, the significance of which is indicated by the fact that its admirable resources in science and engineering are being applied efficiently in the interest of national welfare.

A. Warren Norton, '21, Vice-President of the Alumni Association, presided at the meeting and presented the guest speaker, Reuben H. Markham of the *Christian Science Monitor*, who drew upon his experience of twenty-five years as correspondent in southeastern Europe for an address on "Hitler in the Balkans." Mr. Markham devoted himself to an interpretation of the history of the Balkans through the centuries as a background for understanding the present unrest in that region. Horace S. Ford, the Institute's Treasurer, presented a new motion picture in color of Technology in action, including interesting scenes of undergraduate life. Among these scenes are views of the new Alumni Pool, crew practice, a fencing match, track, and other sports.

Allyne L. Merrill

The committee in charge of the meeting included Francis A. Barrett, '24, of Winchester, chairman; Larcom Randall, '21, Wellesley; C. Yardley Chittick, '22, Waban; James Donovan, '28, Cambridge; and Parker H. Starratt, '30, Hingham.

Cheering Chesterman

SPEAKING from Boston over a long-distance telephone broadcasting circuit, President Compton on February 25 addressed a farewell luncheon given in Pittsburgh in honor of Francis J. Chesterman, '05, life member of the Corporation, who recently was appointed vice-president in charge of operations of the Bell Telephone Company of Pennsylvania in Philadelphia.

Leaving a meeting of the executive committee of the Corporation, Dr. Compton spoke from the Union Club in Boston, paying tribute to Mr. Chesterman, whose loyalty to the Institute is known wherever Technology men gather. A large group of members of the M.I.T.

Club of Western Pennsylvania heard Dr. Compton's message, which follows:

Though members of a democracy one of whose basic tenets is that "all men are created equal," we are today honoring a man because we recognize him as a nobleman in our midst. Frank Chesterman is a nobleman, not because he happened to be born with a title or because he was a favorite of some king, but because he has true nobility of character; because his stature is high in those qualities of ability, loyalty, generosity, and humility which are more important than wealth or title; and because he unconsciously devotes his thoughts and energies to good causes for the help of others and not to his own self-interests.

You who have lived with him have seen more evidence of these qualities than I have, simply because has spent more days of the year in Pittsburgh than in Cambridge. But with a man of Frank Chesterman's caliber one does not have to be with him long to form a true judgment. Early in my connection with the Institute I learned of the respect and affection with which he was regarded by his 1905 classmates and by the members of the M.I.T. Club of Western Pennsylvania. I learned the reason for this respect and affection as I saw him in action during his five years of very loyal service as an elected alumni member of our Corporation — a service so helpful to his alma mater that he was elected a life member in 1938.

While speaking of M.I.T., let me interject a message of greeting to the many Alumni who I know are present at this farewell luncheon. This occasion, which marks Mr. Chesterman's loss from your group, has one consolation for me — Frank Chesterman in Philadelphia will be quite a bit closer to Cambridge than was Frank Chesterman in Pittsburgh and yet not too far away from you to sever completely the close contacts which you and he have built up over so many years.

Frank Chesterman, I thank you for the ways in which you have helped me in my job here, through wise counsel, through loyal support, and through real work on departmental Visiting Committees as occasion demanded. I congratulate you on your appointment to a post of still greater responsibility in that great company which you serve, whose guiding principle has always been to give the best possible service to the public, just as you give personal service to your community.

Charles A. Stone, 1867–1941

IN the death of Charles A. Stone, '88, in New York on February 25, the Institute lost not only a life member of its Corporation but also one of its most generous benefactors. A year after his graduation, Mr. Stone formed what was to become a lifelong partnership with his classmate Edwin S. Webster. At the time of his death Mr. Stone was chairman of the board of Stone and Webster, Inc., which, over the past half century, has become one of the country's outstanding engineering firms, builder of the greater Technology in Cambridge.

Mr. Stone was born in Newton in 1867, the son of Charles H. and Mary Augusta Green Stone. After he was graduated from Technology, Mr. Stone took a position in the research laboratories of the Thomson Electrical Welding Company, forerunner of the General Electric Company. In 1889 he formed the partnership with Mr. Webster, under the name of the Massachusetts Electrical Engineering Company, Stone and Webster, managers. In 1890 the firm was given its first engineering and construction contract for the erection of Pioneer Saccarappa, a hydroelectric installation and transmission line in Maine. This development was one of the first to demonstrate the commercial possibilities of electrical transmission of power, and upon its successful completion the young firm began to expand, contributing importantly to the growth of public utilities throughout the country. Later the company was called upon as consultant on the operation of many electric-light and power plants, as well as electric railways, an activity which led it into the field of management and investment banking. When the need for ships became very urgent during the first World War, Mr. Stone's firm undertook construction of the famous fifty-way shipyard at Hog Island as an assembly plant for parts manufactured in various sections of the country.

The testing floor of the Sloan Laboratories

M.I.T. Photo

Undergraduates to Graduates

CONDUCT of undergraduate activities at the Institute was detailed for members of the Alumni Council at their 218th meeting, in Pritchett Hall on the last Monday in February, by thirteen undergraduate speakers, representatives of the student governing body and of the major activity groups. Their presentations, which were concise but comprehensive, indicated that the distinguished record of undergraduate control of, and responsibility for, undergraduate affairs at Technology is being well maintained by the present generation of students.

Presiding officer in the absence of Henry E. Worcester, '97, President of the Alumni Association, was A. Warren Norton, '21, Vice-President. He introduced Dr. Compton, who discussed briefly the problem of speeding up education to meet the extra demand for engineers and scientists, a demand imposed by the nation's defense program. The proposal that courses be re-arranged to provide for graduation in three instead of four years has disadvantages outweighing its advantages, from the Institute's point of view, he declared. Reports from committees and officers followed.

John B. Murdock, '41, of Tempe, Ariz., President of the senior class and of the Institute Committee, was then introduced as chairman of the undergraduate program. Expressing appreciation of the opportunity, Mr. Murdock presented as speakers William M. Folberth, Jr., '41, of Cleveland, Ohio, chairman of the budget committee, who discussed problems of allocating money to the activities; Joseph H. Myers, '41, of Evanston, Ill., who spoke for the Athletic Association, describing the job of handling twenty varieties of sports; William R. Ahrendt, '41, of Westfield, N. J., chairman of the Walker Memorial committee, who told of the responsibility of assignment of space and arrangements for gatherings; Willard S. Mott, '41, of Bridgeport, Conn., chairman of the dormitory committee, who outlined the conduct of dormitory affairs; Warren J. Meyers, '41, of Winnetka, Ill., general manager of volume XXI of the *Tech Engineering News*, James S. Thornton, '41, of Summit, N. J., general manager of "Technique" for 1941, Robert S. Shaw, '42, of Newton, Mass., general manager of volume XXIV of *Voo Doo*, and Harold E. Dato, '41, of Chicago, Ill., general manager of volume LX of *The Tech*, who discussed their respective publications; Wilfred H. Shaw, '42, of Rochester, N. Y., who described the activities of the Technology Christian Association; Walter S. Eberhard, '42, of Waltham, Mass., who spoke for the 5:15 Club; Rogers B. Finch, '41, of Broadalbin, N. Y., who, as general manager, presented the operation of the Musical Clubs; and Arnold S. Mengel, '41, of St. Louis, Mo., chairman of the student-faculty committee, who explained the duties and activities of that organization.

The student presentations were run off according to a strict schedule which involved the presence of a timing clock set to limit each speaker to five minutes. The talks were well received.

The complete roster of subcommittees for Alumni Day 1941 was presented as follows: *Class Day*, John D. Mitsch, '20, chairman, Henry A. Fiske, '91, James A. Burbank, '16, Eugene Mirabelli, '19; *dinner*, Raymond H. Blanchard, '17, chairman, Arthur L. Shaw, '09, Warren E. Glancy, '13, Josiah D. Crosby, '21, Delbert W. Kendall, '24, Herbert R. Stewart, '24; *exhibits*, John G. Trump, '33, chairman, J. Warren Horton, '14, Francis J. Safford, '34, Robert W. Cloud, '37, Robert J. van de Graaff, Robley D. Evans, George G. Harvey, M. Stanley Livingston, Arthur C. Watson, and Arthur Roberts, Staff; *ladies' events*, Mrs. Leicester F. Hamilton, chairman, Mrs. Howard R. Bartlett, Mrs. Arthur A. Blanchard, Mrs. Raymond H. Blanchard, Mrs. Karl T. Compton, Mrs. Horace S. Ford, Mrs. Carle R. Hayward, Mrs. Ralph T. Jope, Mrs. Henry B. Shepard, Mrs. Stephen G. Simpson, Mrs. Richard Whiting, Mrs. Henry E. Worcester; *luncheon*, Kenneth C. Reynolds, '25, chairman, James Holt, '19, Bernard E. Proctor, '23, Herbert L. Beckwith, '26, Howard R. Staley, '35; *publicity and promotion*, Ralph T. Jope, '28, chairman, Henry B. Kane, '24, James Donovan, '28, Frederick G. Fassett, Jr., John J. Rowlands, Staff; *registration*, Donald P. Severance, '38, chairman, Joseph C. MacKinnon, '13, Robert M. Kimball, '33, Wolcott A. Hokanson, Staff; *ways and means*, Horace S. Ford, Staff, chairman, Albert V. Smith, '20, Delbert L. Rhind, Staff; *twenty-five years in Cambridge*, James R. Killian, Jr., '26, chairman, Alf K. Berle, '27; *symposium*, Edward R. Schwarz, '23, chairman, and entire committee.

Economic aspects of the European situation were the subject of a panel discussion at the 217th meeting of the Council, that for January. Speakers were Ralph E. Freeman, Head of the Department of Economics and Social Science, who discussed broad aspects of procurement and mobilization; Roland D. Parks, Assistant Professor of Mineral Industry in the Department of Geology, who analyzed the mineral resources of Europe with regard to the present struggle; and Samuel C. Prescott, '94, Dean of Science, who considered the food situation.

M.I.T. Photo

Placid while being photographed, the Alumni Pool has been actively used during the present school year.

WARS AND WEATHER

(*Continued from page 249*)

kinetic energy and vice versa, but the unstable waves on the polar front utilize the available energy to a high degree. The intensity with which storms develop will therefore depend on the amount of available energy and the degree of dynamic instability.

Life History of Air Masses. Although the most severe weather occurs in connection with fronts, numerous weather phenomena develop within traveling air masses. Here, again, stability or instability is the deciding factor.

An air mass that is colder than the surface over which it travels is called a "cold air mass." Through heat from the underlying surface, the stratification becomes unstable: Bodies of air from the surface rise, while air from aloft sinks to replace the ascending masses. The result is a broken and variable sky of cumuli, often accompanied by showers and, in pronounced conditions, by squalls, hail, and thunderstorms, depending on the degree of instability.

An air mass that is warmer than the surface over which it travels is called a "warm air mass." Continued cooling from below results in the condensation of water vapor at low levels; stratus, fog, and drizzle are the typical accompanying weather phenomena.

The weather analyst is much concerned with the life history of traveling air masses because on it depends the type of weather that is to be expected. Significant factors are whether an air mass originally came from a polar or tropical source, whether it has traveled over ocean or over land, and how long it has been in contact with the various types of underlying surfaces. Identification of air masses from day to day and construction of their trajectories are problems which must be solved before forecasts are made.

Near the earth's surface the problem of identification is reasonably simple, because air currents follow the earth's surface. In the free atmosphere the problem is not so readily solved. There the air masses ascend and descend and hence they will not remain within weather maps drawn for any fixed levels. To identify the air masses in the free atmosphere, it is necessary to determine the bulging sheets within which the air streams; within each such sheet, the individual masses can be identified by means of some physical property which is conservative.

Although the air masses near the earth's surface are subject to nonadiabatic processes, the changes in the air masses at high levels are mainly adiabatic. A body of air in the free atmosphere will therefore tend to preserve its entropy. On this principle, C.-G. A. Rossby and his collaborators at Technology developed a method of analysis, called "isentropic analysis," which consists in drawing weather maps not for constant levels but for surfaces of constant entropy. Within such an isentropic chart, the individual masses are identified by their specific humidity, which remains constant as long as condensation does not occur.

By means of surface weather charts, isentropic charts, and a number of other types of maps, the forecaster obtains a picture of the state of the atmosphere at successive intervals. If the observations are sufficient in number and cover a large enough area, he can compute future displacements and developments. But regardless of whether the observational basis is sufficient, he has to face the public several times a day and predict, with conviction, what the atmosphere is going to do.

World War II and Long-Range Forecasting. The rapid development of aviation has greatly increased the demand for accurate weather forecasts. In peacetime, aviation is concerned mostly with short-term forecasts for individual trips. In wartime, the major problem is to forecast sufficiently long periods of favorable weather to permit major operations which require several days of preparation. In warfare, a good start is often more than half a victory.

The German invasion of Poland is generally believed to have been successfully timed to coincide with a period of dry weather which robbed the Poles of the assistance of General Mud. The invasion of the Netherlands is believed to have been equally well timed with a major weather period. What is good weather for one purpose may be bad weather for others. For instance, the invasion of Norway, where the polar front theory originated, coincided with a period of real polar front weather. To conclude that this coincidence was due to bad luck or lack of planning would be erroneous. Since the major ports in Norway were undefended, they were the targets at which the invader aimed, and he could therefore use large ships, which could operate in rough weather. To conceal the movement from the British fleet, several days of bad visibility would be just the type of weather desired by the invader.

The much talked-of invasion of the British Isles could hardly be successful if attempted in large ships aiming at the major ports but might well be attempted in small ships, tugs, and barges aiming at unfortified places. For such operations a period with reasonably calm sea, bad visibility at sea, and favorable flying weather over land would be ideal. This combination, extremely rare in fall and winter, is not infrequent in April and May, when a maximum of fog frequency occurs over the North Sea (which then is quite calm) and the visibility over the British Isles is usually good. Considering the tremendous stakes, it might be worth while to wait three seasons for this combination. No wonder, then, that the lords of World War II have turned their attention to long-range forecasting.

A utopian dream for many years, long-range forecasting will probably be one of the useful by-products of the present war. In Germany an institute organized particularly for such forecasting has studied the problem for many years and has probably rendered valuable service during the present crisis. Not only are forecasts made for the trend of the weather a week or two in advance but also for longer trends, such as crop forecasting and so on.

In the United States, considerable research also is in progress. Technology, in collaboration with the United States Weather Bureau, the Department of Agriculture, the Navy, and the Air Corps, has attacked the problem along lines suggested by Dr. Rossby, with results so encouraging that the project is about to be organized on a service basis. (*Concluded on page 266*)

WARS AND WEATHER

(*Concluded from page 265*)

This success does not mean, however, that the problem has been solved in all details. Many negative and a few positive results have been obtained; many more results, of both categories, will follow. At the present moment it seems safe to say that the problem has a solution and to forecast that the solution will be found.

LANGUAGES AND LOGIC

(*Continued from page 252*)

to communicate with their fellows tend to be learned versions of the same method and, while interesting, still evade the question. In similar case is evasion of the question by skipping from the speech sentence, via physiology and "stimuli," to the social situation.

The *why* of understanding may remain for a long time mysterious; but the *how* or logic of understanding — its background of laws or regularities — is discoverable. It is the grammatical background of our mother tongue, which includes not only our way of constructing propositions but the way we dissect nature and break up the flux of experience into objects and entities to construct propositions about. This fact is important for science because it means that science *can* have a rational or logical basis even though it be a relativistic one and not Mr. Everyman's natural logic. Although it may vary with each tongue, and a planetary mapping of the dimensions of such variation may be necessitated, it is, nevertheless, a basis of logic with discoverable laws. Science is not compelled to see its thinking and reasoning procedures turned into processes merely subservient to social adjustments and emotional drives.

Moreover, the tremendous importance of language cannot, in my opinion, be taken to mean necessarily that nothing is back of it of the nature of what has traditionally been called "mind." My own studies suggest, to me, that language, for all of its kingly role, is in some sense a superficial embroidery upon deeper processes of consciousness which are necessary before any communication, signaling, or symbolism whatsoever can occur and which also can at a pinch effect communication (though not true *agreement*) without language's and without symbolism's aid. I mean "superficial" in the sense that all processes of chemistry, for example, can be said to be superficial upon the deeper layer of physical existence, which we know variously as intra-atomic, electronic, or subelectronic. No one would take this statement to mean that chemistry is *unimportant* — indeed the whole point is that the more superficial can mean the more important, in a definite operative sense. It may even be in the cards that there is no such thing as "Language" (with a capital *L*) at all! The statement that "thinking is a matter of *language*" is an incorrect generalization of the more nearly correct idea that "thinking is a matter of *different tongues*." The different tongues are the real phenomena and may generalize down not to any such universal as "Language," but to something better — called "sublinguistic" or "superlinguistic" — and *not altogether* unlike, even if much unlike, what we now call "mental." This generalization would not diminish, but would rather increase, the importance of intertongue study for investigation of this realm of truth.

Botanists and zoologists, in order to understand the world of living species, found it necessary to describe the species in every part of the globe and to add a time perspective by including the fossils. Then they found it necessary to compare and contrast the species, to work out families and classes, evolutionary descent, morphology, and taxonomy. In linguistic science a similar attempt is under way. The far-off event toward which this attempt moves is a new technology of language and thought. Much progress has been made in classifying the languages of earth into genetic families, each having descent from a single precursor, and in tracing such developments through time. The result is called "comparative linguistics." Of even greater importance for the future technology of thought is what might be called "contrastive linguistics." This plots the outstanding differences between tongues — in grammar, logic, and general analysis of experience.

As I said in the April, 1940, Review, segmentation of nature is an aspect of grammar — one as yet little studied by grammarians. We cut up and organize the spread and flow of events as we do largely because, through our mother tongue, we are parties to an agreement to do so, not because nature itself is segmented in exactly that way for all to see. Languages differ not only in how they build their sentences but in how they break down nature to secure the elements to put in those sentences. This breakdown gives units of the lexicon. "Word" is not a very good "word" for them; "lexeme" has been suggested, and "term" will do for the present. By these more or less distinct terms we ascribe a semifictitious isolation to parts of experience. English terms, like "sky," "hill," "swamp," persuade us to regard some elusive aspect of nature's endless variety as a distinct *thing*, almost like a table or chair. Thus English and similar tongues lead us to think of the universe as a collection of rather distinct objects and events corresponding to words. Indeed this is the implicit picture of classical physics and astronomy — that the universe is essentially a collection of detached objects of different sizes.

The examples used by older logicians in dealing with this point are usually unfortunately chosen. They tend to pick out tables and chairs and apples on tables as test objects to demonstrate the objectlike nature of reality and its one-to-one correspondence with logic. Man's artifacts and the agricultural products he severs from living plants have a unique degree of isolation; we may expect that languages will have fairly isolated terms for them. The real question is: What do different languages do, not with these artificially isolated objects but with the flowing face of nature in its motion, color, and changing form; with clouds, beaches, and yonder flight of birds? For as goes our segmentation of the face of nature, so goes our physics of the cosmos.

Here we find differences in segmentation and selection of basic terms. We might isolate something in nature by saying, "It is a dripping spring." Apache erects the statement on a verb *ga:* (*Continued on page 268*)

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LANGUAGES AND LOGIC

(*Continued from page 266*)

"be white (including clear, uncolored, and so on)." With a prefix *nō-* the meaning of downward motion enters: "whiteness moves downward." Then *tó,* meaning both "water" and "spring," is prefixed. The result corresponds to our "dripping spring," but synthetically it is: "as water, or springs, whiteness moves downward." How utterly unlike our way of thinking! The same verb, *ga,* with a prefix that means "a place manifests the condition" becomes *gohlga:* "the place is white, clear; a clearing, a plain." These examples show that some languages have means of expression — chemical combination, as I called it — in which the separate terms are not as separate as in English but flow together into plastic synthetic creations. Hence such languages, which do not paint the separate-object picture of the universe to the same degree as do English and its sister tongues, point toward possible new types of logic and possible new cosmical pictures.

The Indo-European languages and many others give great prominence to a type of sentence having two parts, each part built around a class of word — substantives and verbs — which those languages treat differently in grammar. As I showed in the April, 1940, Review, this distinction is not drawn from nature; it is just a result of the fact that every tongue must have some kind of structure, and those tongues have made a go of exploiting this kind. The Greeks, especially Aristotle, built up this contrast and made it a law of reason. Since then, the contrast has been stated in logic in many different ways: subject and predicate, actor and action, things and relations between things, objects and their attributes, quantities and operations. And, pursuant again to grammar, the notion became ingrained that one of these classes of entities can exist in its own right but that the verb class cannot exist without an entity of the other class, the "thing" class, as a peg to hang on. "Embodiment is necessary," the watchword of this ideology, is seldom *strongly* questioned. Yet the whole trend of modern physics, with its emphasis on "the field," is an implicit questioning of the ideology. This contrast crops out in our mathematics as two kinds of symbols — the kind like 1, 2, 3, x, y, z and the kind like $+, -, \div, \sqrt{\ }$, log — though in view of 0, ½, ¾, π, and others, perhaps no strict two-group classification holds. The two-group notion, however, is always present at the back of the thinking, although often not overtly expressed.

Our Indian languages show that with a suitable grammar we may have intelligent sentences that cannot be broken into subjects and predicates. Any attempted breakup is a breakup of some English translation or paraphrase of the sentence, not of the Indian sentence itself. We might as well try to decompose a certain synthetic resin into celluloid and whiting because the resin can be imitated with celluloid and whiting. The Algonquian language family, to which Shawnee belongs, does use a type of sentence like our subject and predicate but also gives prominence to the type shown by our examples in the text and in Fig. 1. To be sure, *ni-* is represented by a subject in (*Continued on page 270*)

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LANGUAGES AND LOGIC

(*Continued from page 268*)

the translation but means "my" as well as "I" and the sentence could be translated thus: "My hand is pulling the branch aside." Or *ni-* might be absent; if so, we should be apt to manufacture a subject, like "he," "it," "somebody," or we could pick out for our English subject an idea corresponding to any one of the Shawnee elements.

When we come to Nootka, the sentence without subject or predicate is the only type. The term "predication" is used, but it means "sentence." Nootka has no parts of speech; the simplest utterance is a sentence, treating of some event or event-complex. Long sentences are sentences of sentences (complex sentences), not just sentences of words. In Fig. 2 we have a simple, not a complex, Nootka sentence. The translation, "he invites people to a feast," splits into subject and predicate. Not so the native sentence. It begins with the event of boiling or cooking, *tl'imsh;* then comes *-ya* ("result") = cooked; then *-'is* ("eating") = eating cooked food; then *-ita* ("those who do") = eaters of cooked food; then *-'itl* ("going for"); then *-ma*, sign of third-person indicative, giving *tl'imshya'isita'itlma*, which answers to the crude paraphrase, "he, or somebody, goes for (invites) eaters of cooked food."

The English technique of talking depends on the contrast of two artificial classes, substantives and verbs, and on the bipartitioned ideology of nature already discussed. Our normal sentence, unless imperative, must have some substantive before its verb, a requirement which corresponds to the philosophical and also naïve notion of an actor who produces an action. This last might not have been so if English had had thousands of verbs like "hold," denoting positions. But most of our verbs follow a type of segmentation that isolates from nature what we call "actions," that is, moving outlines.

Following majority rule, we therefore read action into every sentence, even into "I hold it." A moment's reflection will show that "hold" is no action but a state of relative positions. Yet we think of it and even see it as an action because language formulates it in the same way as it formulates more numerous expressions, like "I strike it," which deal with movements and changes.

We are constantly reading into nature fictional acting-entities, simply because our verbs must have substantives in front of them. We have to say "It flashed" or "A light flashed," setting up an actor, "*it*" or "light," to perform what we call an action, "to flash." Yet the flashing and the light are one and the same! The Hopi language reports the flash with a simple verb, *rehpi:* "flash (occurred)." There is no division into subject and predicate, not even a suffix like *-t* of Latin *tona-t* ("it thunders"). Hopi can and does have verbs without subjects, a fact which may give that tongue potentialities, probably never to be developed, as a logical system for understanding some aspects of the universe. Undoubtedly modern science, strongly reflecting western Indo-European tongues, often does as we all do, sees actions and forces where it sometimes might be better to see states. On the other hand, "state" is a noun, and as such it enjoys the superior (*Concluded on page 272*)

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LANGUAGES AND LOGIC

(*Concluded from page 270*)

prestige traditionally attaching to the subject or thing class; therefore science is exceedingly ready to speak of states if permitted to manipulate the concept like a noun. Perhaps, in place of the "states" of an atom or a dividing cell, it would be better if we could manipulate as readily a more verblike concept but without the concealed premises of actor and action.

I can sympathize with those who say, "Put it into plain, simple English," especially when they protest against the empty formalism of loading discourse with pseudolearned words. But to restrict thinking to the patterns merely of English, and especially to those patterns which represent the acme of plainness in English, is to lose a power of thought which, once lost, can never be regained. It is the "plainest" English which contains the greatest number of unconscious assumptions about nature. This is the trouble with schemes like Basic English, in which an eviscerated British English, with its concealed premises working harder than ever, is to be fobbed off on an unsuspecting world as the substance of pure Reason itself. We handle even our plain English with much greater effect if we direct it from the vantage point of a multilingual awareness. For this reason I believe that those who envision a future world speaking only one tongue, whether English, German, Russian, or any other, hold a misguided ideal and would do the evolution of the human mind the greatest disservice. Western culture has made, through language, a provisional analysis of reality and, without correctives, holds resolutely to that analysis as final. The only correctives lie in all those other tongues which by aeons of independent evolution have arrived at different, but equally logical, provisional analyses.

In a valuable paper on "Modern Logic and the Task of the Natural Sciences," Harold N. Lee says: "Those sciences whose data are subject to quantitative measurement have been most successfully developed because we know so little about order systems other than those exemplified in mathematics. We can say with certainty, however, that there are other kinds, for the advance of logic in the last half century has clearly indicated it. We may look for advances in many lines in sciences at present well founded if the advance of logic furnishes adequate knowledge of other order types. We may also look for many subjects of inquiry whose methods are not strictly scientific at the present time to become so when new order systems are available." * To which may be added that an important field for the working out of new order systems, akin to, yet not identical with, present mathematics, lies in more penetrating investigation than has yet been made of languages remote in type from our own.

* *Sigma Xi Quarterly*, XXVIII (Autumn, 1940), 125.

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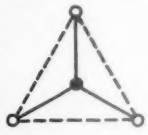
GLASSY GEOMETRY

(*Continued from page 255*)

The second problem which the research at Technology has shown to be answerable in terms of the geometry of atomic arrangement within glass is that presented by the odd properties of glass made from boric oxide, soda, and silica. Direct practical bearing of considerable importance is in this aspect of the research, for the properties of such glass are already being utilized.

Boric oxide by itself readily forms a glass, in which x-ray results indicate that each boron atom is triangularly bonded to three oxygens, thus:



Each oxygen is bonded to a second boron in an adjoining group. When the batch consists of silica and boric oxide, the expansion coefficient of the glass is less than that of the straight boric-oxide product, for each silicon is bonded to the surrounding structure in four directions (as in the soda-silica glass described earlier), whereas the borons bond in only three directions. If boron atoms can be made to shift from their natural triangular bonding to the tetrahedral bonding which the silicon atoms naturally assume, the expansion coefficient of a boron glass might naturally drop.

Here is where the "boric-oxide anomaly" operates. When a glass batch consists of boric oxide and soda, both x-ray results and physical properties indicate that for small soda content the extra oxygen introduced by the soda (Na_2O) is used up by changing as many as possible of the boron atoms from their triangular bonding into fourfold tetrahedral bonding. The change is equivalent, as far as expansion coefficient is concerned, to replacing a boron by a silicon atom. This change occurs for a soda content up to 13 per cent.

Why do as many boron atoms as possible change when the soda content is 13 per cent or under; and why do they stop changing for a soda content greater than 13 per cent? The answers appear to lie in geometrical considerations closely resembling those which we have seen to govern the question of immiscibility in calcium-silica glass. Again it is a matter of whether ions in the mixture can find suitable surroundings in the volume of material available. If the borons all remain in triangular bonding, the extra oxygen introduced by the soda results in a surplus of oxygen atoms, so that some will be bonded to two borons, and some to only one. These latter oxygens will then be unsaturated and will attract the sodium ions, which seek to surround themselves with unsaturated oxygens. One such oxygen will be present for each sodium ion; hence again it will be necessary for the wandering ion to be in contact with more than one oxygen, and again the question of distance and volume will arise. If the sodium content is small and the ions are uniformly dispersed, as in a homogeneous glass, each sodium ion is geometrically unable to have a suitable surrounding of oxygens. (*Concluded on page 274*)

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GLASSY GEOMETRY

(*Concluded from page 273*)

The shifting of boron atoms from triangular to tetrahedral configuration, however, increases the number of unsaturated oxygens, so that the sodium ions have better opportunity for securing suitable surroundings. The change of borons to tetrahedral bonding produces four times as many unsaturated oxygens. In a system of soda and boric oxide, the distance between two sodium ions in contact with oxygens of the same boron-oxygen tetrahedral group must be 5.73 angstrom units, so that for each sodium ion in the mix a volume of 188 cubic angstroms of glass is necessary. A soda content of 12.4 per cent will supply sodium ions in proper proportion to this volume, if as many as possible of the boron atoms change to the tetrahedral co-ordination. For less than 12.4 per cent of soda, the change should be complete, and above 12.4 per cent there is no need for further change, since then an ample supply of unsaturated oxygen atoms will be provided by the soda itself.

The ideas involved here probably underlie the method used in making the new "preformed" glass developed by Corning, which is pictured on page 255. This process starts from a batch containing soda, boric oxide, and silica, which melts to a clear homogeneous single-phase glass. From this, the desired object (for example, a beaker) is readily fabricated. The article is then given a special heat treatment during which some change takes place in the glass, presumably involving a shift of some of the borons to tetrahedral bonding, and as a result a tendency occurs for the sodium ions to surround themselves by the unsaturated oxygens of the tetrahedral groups consisting of a boron and four oxygens. There is hence a tendency for the sodium and boron groups to cluster together — a tendency toward segregation.

If the glass article then is treated with an acid, most of the component consisting of soda and boric oxide leaches out, leaving behind a porous skeletonlike structure which is about 96 per cent silica and 4 per cent boric oxide. Further heat treatment of the article causes the porous structure to contract to a homogeneous glass — the shrinkage in volume running as high as 35 per cent. The article maintains its original shape, however, in spite of that shrinkage. The result is a finished product made of a glass which is nearly pure silica and which has nearly the same small expansion coefficient as fused silica, but which has been made without the expense and difficulty of direct manufacture from silica. Like articles made of fused silica, the preformed glass can be heated to a cherry red and immersed in water without damage.

"PATTERNES AND SAMPLES"

(*Continued from page 258*)

might well visit the physics and chemistry departments, where he would be given some insight into the fundamental developments which immediately preceded the industrial revolution. Subsequent visits to the raw materials departments (fuels and metals and agriculture, textiles, and forestry) would give him an understanding both of the striving of man to secure raw materials and of the application of the fundamental sciences in

the processing and manufacture of products of mine and farm. Logically, the visitor should next devote time to the power and transportation departments; then to graphic arts and the cultural aspects of the Machine Age; and finally to the departments of engineering construction and of the medical sciences, wherein the development of the modern industrial metropolis may be studied from the points of view of the engineer and the public-health expert.

Each section is entered from or near the north hall, and visitors are unconsciously guided through room after room until they leave the sequence not far from the entrance. By-passes are provided at numerous places, and while visitors are encouraged to proceed logically, there is no compulsion to follow a prescribed route.

More detailed discussion of one of the departments, that of fuels and metals, will suggest the activities of a teaching museum. When man discovered the metals, he became civilized; when he uses fuels, he lessens human drudgery. In presenting these facts, the department portrays: (1) basic principles of geology; (2) geology of ore deposits and ore mining and concentration; (3) geology, mining, preparation, and utilization of coal; (4) geology, prospecting, drilling, production, transportation, and refining of petroleum, as well as the properties and uses of its countless products; (5) geology, mining, and transportation of iron ore, its reduction to pig iron, the conversion of pig iron into steel, and the fabrication of this steel by rolling, forging, casting, machining, cold working, and welding; (6) production and fabrication of the important nonferrous metals; (7) properties of metals, how measured, and how improved by alloying and heat treatment; and (8) mining of gem minerals and their conversion into gems.

To illustrate and explain these facts, the sequence includes a coal mine; an ore-concentration table in operation; a full-size oil derrick and pumping-oil rig; a model petroleum refinery in simulated operation; a model of a continuous hot-strip rolling mill, in which slabs of lead are rolled in a blooming mill and are passed through roughing and finishing stands to become strips twenty times their original length; the (*Continued on page 276*)

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"PATTERNES AND SAMPLES"

(*Continued from page 275*)

making of small upset forgings; a complete, working, gray-iron foundry; five small machine tools — lathe, drill, miller, shaper, and grinder — which may be hand-operated by the visitor so that the five fundamental machining operations may be learned; demonstrations of electroplating, welding, and heat treating of metals; and physical testing apparatus in operation.

This somewhat lengthy list includes but a small percentage of the exhibits on display but gives, it is hoped, an understanding of the types of exhibits and of the scope of the department. It should be repeated that exhibits are not placed at random but are arranged in logical sequence.

The coal mine and the foundry are two of the most elaborate displays and are very popular. Coal is our principal source of power. The coal industry is therefore of outstanding importance and is entitled to the preferred space allocated to it. The feature exhibit of this section is the coal mine, a full-size representation of a modern bituminous mine. The surface equipment consists of a six-by-ten-foot Nordberg cylindroconical drum hoist, an Allen and Garcia end-lift head-frame standing sixty-five feet above ground level, and a seven-by-three-foot Jeffrey ventilating fan at the air shaft. The visitor is lowered to the shaft bottom apparently five hundred feet below the surface, where he sees a rotary dump and an automatic weight recorder dumping and weighing coal. Later he boards a "man trip" and is hauled to the working face, apparently a mile or so from the shaft bottom. He alights from the train and passes through a number of rooms in which practical coal miners demonstrate and explain the latest types of undercutting, drilling, and loading machines. Throughout the mine the visitor sees a faithful portrayal of a portion of Illinois seam No. 6. Slabs of coal, from draw slate to clay bottom, were removed from the rooms of a Macoupin County mine, were transported to Chicago, and were erected to duplicate the rooms from which the slabs were taken. On leaving, the visitor witnesses a demonstration of the flame safety lamp and other apparatus and methods used to promote mine safety. The combination of reality and illusion has been successful, we believe, in giving the visitor a true picture of modern coal-mining methods in an environment which faithfully portrays the actual mine. The mine was operated from 1933 to 1938 and has been re-opened. During the first five years of its operation 600,000 persons visited it.

During the past few years a committee of the Chicago chapter of the American Foundrymen's Association has joined with the department staff in the planning and erection of an operating foundry. Here the visitor sees the melting of iron in both electric furnace and cupola; the pouring of the molten iron into sand molds; the separation of castings and sand at the vibrating screen shakeout; the cleaning of the castings in a modern equivalent of the tumbling barrel; the grinding of the cleaned castings; the reconditioning of the sand and its movement by bucket elevator and conveyer belts to hoppers over the molding machines; the forming and baking of cores; and the making of molds and placing them on roller conveyers ready for the next pouring. In other words, he witnesses the making of a gray-iron casting from pattern to finished article. All machines, equipment, supplies, and even the pig iron and sand were donated by some sixty contributing companies. The glamour of hot metal and the understanding of how everyday articles are made have resulted in this foundry's vying in popularity and educational value with the coal mine.

It will be noted that some exhibits are historical, others are modern, and still others show the evolution from the old to the new. Some exhibits are static, some operate continuously, some are operated by the visitors, whereas others are demonstrated by the attendants. Exhibit methods include two-dimensional and three-dimensional static material, dioramas, motion pictures, slide projectors, replicas, modern commercial machinery, operating models of processes and plants, and demonstrations of scientific principles and their industrial applications.

The attendants have a very important function — they are lecturers and demonstrators, not guards — and in the course of their lectures and demonstrations use

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the exhibits as props. The combination of attendant and exhibit is far more effective than either alone. For example, in the coal mine it is desirable that the men be experienced coal miners in order that they look the part and that they be qualified to answer intelligently questions regarding mining practices. The typical man in the coal mine at the present time is a high-school graduate who, prior to joining the museum staff, had twelve years of coal-mining experience.

In other sections of the museum the best results are obtained by using young men, graduates of universities or technical schools, who have had experience in research or industrial work, and who, in many instances, are working for higher degrees at near-by colleges and universities. The men are moved about from position to position and thus become acquainted with many exhibits. They are thereby broadened educationally, and the possibility of their becoming bored through isolation is minimized.

The method of operation is as follows: At scheduled times a demonstration is started near the entrance to a sequence, and a group of visitors gather. On the completion of this demonstration the group is turned over to another man, who explains other exhibits, and so on throughout the section. The frequency of demonstrations depends on the attendance, an attempt being made to limit the size of groups to twenty-five or thirty. Student groups are handled similarly, although it is customary for the instructors to make arrangements prior to their arrival so that proper facilities will be at their disposal in the sections they wish to visit.

An ideal museum of science and industry should be an educational tool, not a repository of dust-laden relics. It should be dynamic, not static; inspirational, not dull. It should depict the technical ascent of man and the economic and social consequences of that ascent. It should teach scientific principles and their industrial applications. The correlation of scientific facts, of the sciences one with the other, of science to industry, and of industry to everyday life should be forcefully shown by the orderly presentation of exhibit material. By exhibits, dynamic and static, by demonstrations, by illustrated lectures, and by adequate, usable library facilities, these desirable aims may be accomplished.

THE TREND OF AFFAIRS

(*Continued from page 246*)

vastness tends to keep the average reader away from them. More than such siphoning, however, is done by the volume.

The economic, social, and political effects of the rise of technological culture are pretty thoroughly explored by the Rosens, who employ the instructive case study to good purpose, applying it to the cigar industry, to doctors and hospitals, and to government and education and radio as a means of illuminating their general discussion of the three types of effect. The increasingly evident and urgent need for technicians qualified for constant effort in the study of future trends is clearly established by their discussion. (*Concluded on page 278*)

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THE TREND OF AFFAIRS

(*Concluded from page 277*)

The citizen whose world has been changed by grace of technological means which he too often takes for granted must, if he is to act sensibly in the direction of preserving fundamental values, have information upon which to base his decisions. For this reason, the Rosens well argue, it is imperative that research in the social sciences result in conclusions which can be and are clearly stated in terms meaningful to the layman. Their own work measures up fairly well to this entirely justified standard, save in unfortunately numerous errors in the technic of language, not all of which can be blamed on the publisher's editor or proofreader, as well as various errors in the transcribing of fact.

The Smellies

LATEST addition to the armament by which those temples of illusion, the movie theaters, strive to capture reality and make things easier for the patron's already coddled imagination is the use of odor synchronized with the screen action. The invention of two Swiss chemists, the process consists essentially of the introduction of appropriate odors through a theater's ventilating system for the length of time required by a scene. Thus the lovers tread over the soft carpet of the forest to the accompaniment of piny perfumes. Or it may be a delicatessen store.

Incisively, if inelegantly, *Variety* has labeled these efforts the "smellies." Commenting on experimental tryouts in the Midwest, it says that the company which has developed scented movies is now working along the idea of a "$10 dingbat which will go readily into any theater's ventilating system" and is attempting to build up a stock of basic odors suitable for use with a majority of features. The magazine adds that the experiment has caused some movie-goers to return to the theater in order to see again the high-mass scene in *Knute Rockne — All American*. They could not believe that they had actually smelled candle wax and incense; they felt that imagination had got the better of them.

With over a thousand available aromatics, many of them synthetics which can be obtained with uniform properties and at moderate cost, perfumers are having little difficulty in finding industrial applications for their wares. Long used on gloves and money and in soap and cigarettes, perfumes are also aiding the sale of fly sprays and dyed textiles (see The Review for June, 1938, page 350). Other recent applications, most of them made necessary by the increased use of chemicals in consumers' products, include raincoats (whose resistance to water may depend on a wide list of plastics and solvents) and shoes (many of which are now put together with very strong synthetic or rubber cements). At the request of the New York World's Fair management — until the procedure was found too expensive as a nightly feature — one perfume company replaced the fishy smell which some noticed during the nine-o'clock fountain display with more suitable odors.

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